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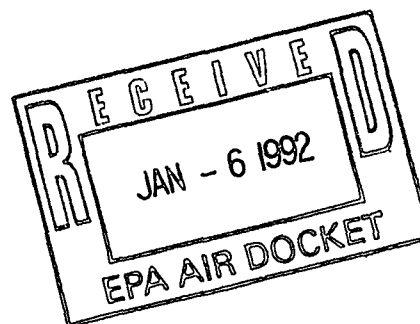
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January 6, 1992

BY HAND

Ms. Mary T. Smith
Director
Field Operations and Support Division
Office of Mobile Sources
EN-397F
U.S. Environmental Protection Agency
401 M Street, S.W.
Washington, D.C. 20460



Re: Public Docket No. A-91-46

Dear Ms. Smith:

For the purpose of completing the record concerning Ethyl Corporation's waiver application for the HiTEC® 3000 performance additive, the materials listed below (and attached) are submitted to the docket. The information included in these documents is not new, but merely documents and/or supplements what has already been stated to EPA in this proceeding.

- o "Study of Effects of HiTEC 3000 Use on Refinery Operations," Turner, Mason & Company (November 1991).
- o "Correlation and Associated Emissions Tests" and "Sequence of Recent Events Regarding Correlation and Associated EPA Ann Arbor Tests" (May 29, 1991).
- o Letter with attachment to Mary T. Smith from Lt. Gen. Jeffrey G. Smith dated June 7, 1991.
- o Letter with attachment to Mary T. Smith from Lt. Gen. Jeffrey G. Smith dated July 8, 1991.
- o Letter to Mary T. Smith from Lt. Gen. Jeffrey G. Smith dated July 9, 1991.
- o Letter to Mary T. Smith from Lt. Gen. Jeffrey G. Smith dated July 11, 1991.
- o Letter to J. Michael Davis from Donald R. Lynam dated May 13, 1991.

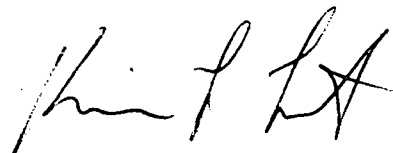
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Ms. Mary T. Smith
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- o Letter to J. Michael Davis from Ben F. Fort, Jr. dated May 13, 1991.
- o Letter to J. Michael Davis from Gerard D. Pfeifer dated May 13, 1991.
- o Letter to J. Michael Davis from Lucinda Minton Langworthy dated May 13, 1991.
- o Letter to J. Michael Davis from Donald R. Lynam dated July 10, 1991.
- o Letter to J. Michael Davis from Chris Whipple dated April 29, 1991.
- o Letter to J. Michael Davis from Ralph L. Roberson dated April 26, 1991.
- o Memorandum to J. Michael Davis from H. Daniel Roth dated May 13, 1991.
- o Letter to the Honorable Henry A. Waxman from William G. Rosenberg with Attachment dated December 10, 1991.
- o Letter to Mary T. Smith with attachment from Jeffrey G. Smith dated December 16, 1991.

If you have any questions concerning this submission, please do not hesitate to call one of the undersigned or Jeff Smith (202-223-4411).

Sincerely,



John J. Adams
F. William Brownell
Kevin L. Fast

Enclosures

cc: Public Docket A-91-46

**STUDY OF EFFECTS
OF HITEC 3000 USE
ON REFINERY OPERATIONS**

November 1991

George W. Michalski
John R. Auers
Robert E. Cunningham

TURNER, MASON & COMPANY
Consulting Engineers

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STUDY OF EFFECTS OF HITEC 3000 USE

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GWM
11/26/91

INTRODUCTION

objective

The objective of our study for Ethyl Corporation (Ethyl) was to determine the effects of the use of the manganese performance additive HiTEC 3000 in unleaded and reformulated gasoline on refinery crude oil demand, refinery emissions and gasoline properties. These effects, along with test data on automotive emissions, could then be used to evaluate Ethyl's request for a waiver for the use of HiTEC 3000 in gasoline.

In order to accurately calculate these effects, we used a linear programming (LP) model of PADD III conversion refineries to compare operations without and with HiTEC 3000. Results from PADD III were extrapolated to the entire U.S. based on results of prior studies. All reformulations explored were within real, practical refining limits.

study

background

Prior to initiating this study, Turner, Mason & Company (TM&C) had performed a gasoline reformulation screening study for the American Petroleum Institute (API) in 1989 and economic analysis of possible gasoline reformulations for the Air Quality Industry Research Program (Auto/Oil) in 1990-91. In these studies, we significantly modified our refinery LP model to represent possible additional processing required to reformulate gasoline. These model changes permitted meeting reformulated gasoline property criteria either singly or in combination.

*capability
of TM&C*

TM&C has been well recognized as having the best refining industry LP modeling expertise and competence available in consulting firms over the past seven years. TM&C has conducted industry studies for DOE, EPA, National Petroleum Council (NPC), API, Western States Petroleum Association (WSPA), Auto/Oil, Motor Vehicle Manufacturers Association (MVMA) and International Lead and Zinc Research Organization (ILZRO). Our LP model and/or input data with gasoline reformulation has been sold to several major oil companies. It has also been used in gasoline reformulation studies for other associations, groups and individual companies.

*scope
of
report*

This report presents our findings from eight PADD III conversion refinery LP model cases involving the range of likely reformulated and oxygenated gasoline demands in 1995 Summer and winter cases with and without HiTEC 3000 were included. From the results of these cases, we extrapolated to obtain the U.S. savings of crude oil, reduction of refinery emissions and likely changes in gasoline properties available through the economical use of HiTEC 3000

EXECUTIVE SUMMARY

- The summer and winter 1995 cases evaluated covered a range of reformulated/oxygenated gasoline demands:
 - A minimum case assuming that reformulated gasoline is used only in mandated areas, and
 - A maximum case assuming a high level of opt-in as estimated by DOE.
- In the minimum reformulation case, the use of HiTEC 3000 in all U.S. reformulated and conventional gasoline would save 85 thousand barrels per day (MBPD) of crude on an annual average basis. In the maximum reformulation case, 47 MBPD of crude would be saved. Crude savings are significantly higher in the summer but are still 24 to 28 MBPD in the winter.
- Using HiTEC 3000 will reduce petroleum refinery process furnace emissions. Calculated total furnace emissions should be reduced at all U.S. refineries by about:

	Tons Per Year	
	Minimum Reformulation	Maximum Reformulation
NO _x	2,700	1,650
CO	2,150	1,220
Particulates	1,980	1,080
SO _x	3,760	2,360
CO ₂ (thousands)	1,800	1,180

- The use of HiTEC 3000 will improve the properties of both reformulated and conventional gasoline and thereby

reduce air toxics. Changes in hydrocarbon type are as follows:

	Summer			Winter		
	Pool	Reformulated	Conventional	Pool	Reformulated	Conventional
<u>Minimum Reformulation</u>						
Manganese, mg/Gal.	26	21	28	8	8	8
Benzene, %	-	-	-	(0.09)	(0.13)	(0.05)
Aromatics, %	(1.8)	(2.2)	(1.6)	(0.7)	(0.4)	(0.8)
Olefins, %	-	-	-	(0.1)	(0.2)	0.1
<u>Maximum Reformulation</u>						
Manganese, mg/Gal.	15	15	15	7	6	8
Benzene, %	-	-	-	(0.09)	(0.03)	(0.23)
Aromatics, %	(1.1)	(1.3)	(0.7)	(0.5)	(0.5)	(0.4)
Olefins, %	0.1	(0.2)	0.6	-	0.5	(1.3)

- Our refinery model results indicated that HiTEC 3000 use in gasoline would include economic levels of about 15 to 26 mg Mn/gallon in summer and 7 to 8 mg Mn/gallon in winter in 1995.
- As specified by DOE, gasoline demand in 1995 was assumed to be the same as in 1990. Gasoline grade ratios were set at 1990 levels, except that leaded gasoline was prorated to unleaded grades to maintain the same pool octane as in 1990. These are very conservative assumptions.

ANALYTICAL APPROACH

LP models

We used our refinery LP model for the aggregate group of conversion refineries in PADD III. Aggregate modeling permits determination of refining industry capability and costs without revealing any specific refinery's confidential data. TM&C's PADD III conversion refinery aggregate model was originally developed and extensively calibrated for prior studies. TM&C's model was already extensively modified to include gasoline reformulation capability. It had been calibrated to accurately predict aromatics, olefins, benzene, sulfur, RVP and 90% distilled temperature (T90). It was extensively reviewed by API and Auto/Oil LP experts.

assumptions and bases

We developed and agreed upon all of the assumptions and bases for this study with Ethyl in consultation with DOE. Major assumptions included: supply and demand forecasts, fixed product requirements, crude and product pricing outlook, refinery process unit capacities and utilization limits, new unit sizing, product grade ratios and properties, crude and minor product flexibilities, and MTBE supply/cost outlook. These assumptions will be covered in more detail in a major report section below.

We determined with Ethyl that 1995 model runs producing both minimum and maximum outlook levels of reformulated/oxygenated gasoline should be made. We made LP model runs for summer and winter, allowing investment in additional refining facilities. In the 1995 base cases, all gasoline was produced without HiTEC 3000. We then ran

each of these four cases allowing optimum use of HiTEC 3000.

*analysis
of results*

We compared the results of the HiTEC 3000 cases to the corresponding base case, using a Lotus 1-2-3 program to generate pertinent tabular refining industry results. These results included the run basis, gasoline properties, and material balance changes. We reviewed all aspects of the LP runs to be sure that process operations, product blending and marginal economics were reasonable.

*optimized
reformulation
costs*

The LP technique systematically finds the least cost solution for any given case. Although there are hundreds of feasible solutions with the large number of variables that can be modified, the LP seeks the one mathematically optimal solution. The advantage of comparing a HiTEC 3000 case LP run against a base case LP run is that both are optimized, and the differences reflect the least-cost refinery operations. This technique is much better than comparing simulation cases because it offers a consistent approach to least cost and not an arbitrary selection of alternate feasible solutions. This approach avoids significant under- or over-estimation of the HiTEC 3000 effects on refinery operations.

*refinery
variations*

All of the calculated HiTEC 3000 effects are based on our modeling aggregation of refineries and do not apply to any individual refinery. Actually, every refinery is unique in processing raw materials, products and product properties.

Numerous model limits were added to correspond with realistic refinery situations and to avoid over-optimization. However, the nature of refining industry LP models is such that their tendency to over-optimize cannot be totally eliminated. Although we calculated the average or typical effect for the group of all conversion refineries, results are low or conservative due to unavoidable over-optimization in our aggregate model.

*relevant
refining
costs*

Each LP run was optimized based on a combination of relevant refining costs in constant 1991 dollars. Each LP solution considers raw material cost, variable product prices, variable operating costs, incremental capital costs, and additional fixed operating costs. For each case, we made several iterative runs to optimize new process plant sizing and provide one new unit of each type for each refinery for more accurate capital cost. Off-line, we considered external effects, including MTBE investment costs, physical gasoline blending constraints and the impact of BTU content on mileage, to maintain constant total miles traveled.

*critical
review*

The shadow values on each run were checked to make sure the model was not unreasonably constrained. We applied our well-seasoned judgment to ascertain that the solution was realistic and that there were no anomalies. We also checked the strategies chosen by the model for realism and compared the results between different cases for consistent

strategies. Differences had to be understandable and reasonable.

ASSUMPTIONS

*general
and
investment*

The assumptions and bases for our study are outlined in detail on the A- tables attached. All of our work was done in constant 1991 dollars. We allowed investment in reformulation processes in the base cases. Reformulation process units are sized to provide one unit for each refinery.

*supply
and
demand*

As specified by DOE, we assumed no growth in product demand from 1990 to 1995. This is a very conservative assumption. The U.S. daily average supply and disposition of crude oil and petroleum products for 1990, as reported by the Energy Information Administration, is shown in Table A-2. Corresponding information for PADD III is shown in Table A-3. We adjusted demands on a seasonal basis based on the data presented in Table A-4. Finally, we deducted the products from PADD III simple (non-conversion) refineries shown in Table A-13 to arrive at demands for our PADD III conversion refinery model.

flexibility

Product demands for finished motor gasoline and middle distillates, as well as most minor products, remained fixed at the unreformulated level in all reformulation cases. Only high-sulfur residual fuel oil, coke, C_4 and lighter products were allowed to vary. Nigerian, United Kingdom and Saudi Arabian crudes were allowed to vary, along with MTBE, methanol, natural gasoline, purchased butanes and natural gas feed to the hydrogen plant. All other raw materials were fixed. Finished gasoline output was adjusted to maintain constant miles traveled when the BTU content shifted, based

on the 0.8 R factor used by the EPA in their RVP reduction study. That is, 0.8 of the differences (up or down) in gasoline heat of combustion are reflected in vehicle fuel economy.

*gasoline
grade
ratios*

Our outlook for gasoline grade ratios is developed in Tables A-5 through A-7. At DOE direction, we conservatively estimated that 1995 grade ratios would not change from 1990 levels. We used 1990 gasoline movements between PADDs, along with demand ratios for each PADD, to estimate PADD III refinery gasoline production ratios. Finally, we assumed that simple refineries would make only regular grade gasoline and determined conversion refinery gasoline grade ratios by difference.

Within the octane grades, we divided the gasoline pool into two categories: conventional and reformulated/oxygenated gasoline. We considered summer and winter cases with both minimum and maximum opt-in estimated by DOE, as shown in Table A-1.

*gasoline
specifications*

Background data for the LP gasoline specifications are shown in Tables A-8 to A-10 and A-15. We set the reformulation specification determined by EPA:

- Benzene at 0.95% volume maximum average; and
- Aromatics at 25% volume maximum average with no compliance margin.

Reformulated gasoline was allowed no increase in olefins, sulfur and T90 from 1990 levels. Conventional gasoline benzene, aromatics, olefins, sulfur and T90 were not allowed to increase over 1990 levels. The resulting specifications are shown in Table A-15. The LP model gasoline pool included three octane grades of combined reformulated and oxygenated gasoline, as well as three octane grades of conventional gasoline.

octane
specifications

We based octane specifications on the NPRA survey of PADD III 1989 production adjusted for changes from 1989 to 1990 from NIPER data. These NIPER data also indicate that winter gasoline grades have the same octane as summer grades. Basic octane specifications are shown in Tables A-8 through A-10 and summarized below:

	1995 <u>(R+M)/2</u>
Unleaded Regular	87.4
Unleaded Midgrade	89.2
Unleaded Premium	92.9

Octane response to HiTEC 3000 is dependent on aromatic content, clear octane number and sensitivity (the difference between research and motor octanes). Gains for 1/32 gm Mn/gallon range from 0.6 octane in premium to 0.9 octane in regular grades. Manganese level was optimized by means of a series of straight line segments representing its octane response curve.

diesel fuel

We assumed that 80% of PADD III No. 2 diesel fuel would be 0.05% sulfur. The simple refineries would produce higher sulfur off-road diesel only.

capacities

Our basis and initial unit capacities for the model are shown in Tables A-11 and A-12. We allowed the model to add economic refining capacity in all cases.

MTBE

We allowed the conversion refineries to produce maximum MTBE from isobutylene in their cat-cracked and coker butylene/butane streams. (No ether production was permitted in refineries with less than 20 MBPSD of FCC capacity, because the small ether unit would be uneconomic.) All other ether was assumed purchased in the form of MTBE from outside sources, with no butane dehydrogenation capacity included in the refineries. We estimated the investment for outside MTBE from the Middle East. Our estimated MTBE price and investment costs were very close to those made independently by other contractors. The price paid by refineries for purchased MTBE includes a 40¢/G capital charge to pay out the very large outside investment in MTBE.

pricing

We used TM&C pricing shown in Table A-14 based on recent history prior to the Persian Gulf war. Based on the consensus of numerous forecasts, we selected a \$20-per-barrel price for West Texas Intermediate crude. We provided the pricing for other crudes, low sulfur diesel and minor

products and developed the full slate of prices based on TM&C crude and product price differentials.

REFINERY
LP MODEL
DEVELOPMENT

Our LP model represents the composite group of 44 conversion refineries in PADD III, which produce about 45% of U.S. gasoline. We use the concept of an average or typical refinery to more easily understand the results.

*industry
model*

TM&C developed the composite PADD III conversion refining industry model originally for refining industry studies conducted for the Federal Energy Agency (FEA) and the Department of Energy (DOE) in the 1970s. It was upgraded, modified and very extensively validated using a 1985 industry survey for our National Petroleum Council (NPC) study of gasoline capability and cost. We then used the model in several multi-client subscription studies and a vapor pressure reduction cost study for the API in 1987.

*gasoline
reformulation
model*

Gasoline reformulation capability was developed and added in a 1989 gasoline reformulation screening study for API. Reformulation capability was further improved and additional gasoline properties were calibrated in 1990-91 for the Auto/Oil study. This enhanced gasoline reformulation model was used for this study. We converted the LP model in 1990 to run on a personal computer instead of on a large mainframe computer. TM&C's reformulation capability LP model and/or data have been sold to several companies, and others are considering purchasing our LP model and/or these reformulation data. Adding gasoline reformulation with about 80 options doubled the size of our LP model by requiring over a dozen new refining processes and much

more extensive gasoline properties on many narrow gasoline cuts.

*model
validation*

The TM&C model has been extensively validated with historical data. Validation involved comparison of model results with industry data, then adjusting the model data until model outputs agreed with historic data. For the NPC validation, crude and major product rates were matched exactly. After allowing residual fuels, butanes and lighter, coke and gain to vary, DOE material balances for these products were matched within 0.3% of total input. Individual conversion units throughput was matched within 8% for a total conversion unit throughput match within 5%. Catalytic cracker conversion matched within 5%. Model utilities usage and individual fuel components were matched to DOE data within 4% of their absolute levels.

Gasoline RVP and octane numbers and distillate fuel sulfur levels were calibrated to survey levels. Component octane numbers were adjusted where necessary to match NPC survey component data. Then octane factors were adjusted until gasoline lead level was within 0.1 gram per gallon, reformer throughput was within 15% and reformer severity was within 0.5 octane number.

model

In our 1987 RVP study for API, gasoline RVP and butane content were calibrated against industry survey data to fit within 0.1 RVP and 0.1% butane. During our work for

calibration

Auto/Oil, the gasoline sulfur, aromatics and olefins content, plus 90% distilled representation, were calibrated against the NPRA survey results conducted for Auto/Oil. Results of this calibration showed agreement on aromatic and olefin contents within 1.4% each. The 90% distilled temperature agreed within 3°F. Model sulfur content matched the survey and NIPER results within 40 ppm. During a 1990-91 study for WSPA/GM/CARB on RVP/DI impacts, benzene, T50 and T10 were calibrated in our LP model. The model predicted benzene fit within 0.2%, and T50 and T10 matched within 3°F of physical blends. These differences are all less than the test reproducibilities and most are significantly less.

The investment estimates for new processes were extensively reviewed by the engineering staff of each participating oil company in Auto/Oil. All of our investment estimates were within 20% of individual unit estimates provided by individual participating companies and within less than 5% of the composite estimate of all of the companies.

*reformulation**options*

- ether

aromatics

The required use of ether increases octane and thereby makes aromatics reduction much less costly. Aromatics are reduced primarily by narrowing the catalytic reformer feed boiling range and reducing reforming severity, plus fractionating out the back end of the heavy cat-cracked gasoline and reformat. The heavy low aromatic hydrocrackate and straight run naphtha are routed to treating and middle distillates. The heavy, highly aromatic gasoline

fractions are routed preferentially to resid cutter, and finally, if necessary fed to hydrocracking to make lighter gasoline. Reducing aromatics concomitantly reduces T90 (the 90% distilled point).

– *benzene
and RVP*

Benzene is reduced by routing benzene precursors around the reformer to gasoline. It is further reduced by extraction from reformat. Reformat feed prefractionation and BT reformat fractionation can concentrate benzene prior to extraction. We have allowed extra benzene production from reformat to replace toluene that is normally fed to hydrodealkylation plants outside of refineries. Net petrochemical aromatics production is held constant. RVP is reduced by butane fractionation and sale. Low RVP levels require FCC C₃ fractionation and C₃ olefin processing to ether and alkylate.

BASE

CASES

RESULTS

We ran summer and winter base cases for both the minimum and maximum reformulated gasoline scenarios. These cases determined the facilities required to make reformulated gasoline without HiTEC 3000 and established the base material balances for the study. Since the costs of these cases were not the focus of our study, we have not reported the investment requirements.

*raw**materials*

Table B-1 shows the raw material input rates detail for all four base cases. Crude oil provides about 93% of input requirements in the summer, while the rest is unfinished and other products. In the winter, crude provides only 88% of input because more butane and MTBE are required. PADD III conversion refineries sell some reformat to and receive vacuum gas oil from simple refineries. Significant MTBE and some vacuum gas oil, naphtha and vacuum resid is imported. The rest of the raw materials shown are derived from natural gas liquids.

products

Refinery product rates are shown in Table B-2. The models were required to exactly meet the demand for most products. Residual fuel, propane and marketable coke were allowed to seek their optimum levels. Optimized process gas and catalytic coke were produced and then consumed as plant fuel. Demands for reformulated and conventional gasoline have been adjusted to hold vehicle miles traveled constant with different heats of combustion.

HiTEC 3000

CASES

RESULTS

Results from the HiTEC 3000 cases are summarized in Tables 1 through 4, showing estimated crude savings, refinery emissions changes, octane improvement costs and HiTEC 3000 consumption. Additional details are provided in C- tables for the minimum reformulation cases and in D- tables for the maximum reformulation cases. Each set of tables includes the following:

- 1 Run basis and gasoline pool properties;
- 1A Reformulated gasoline pool properties;
- 1B Conventional gasoline pool properties; and
- 2 Refinery raw material and product rate changes.

aromatics

Addition of HiTEC 3000 reduces the need for aromatic octanes, hence, it reduces reforming severity. In reformulated gasoline both MTBE and HiTEC 3000 reduce aromatic content. In the minimum summer reformulation case, aromatics in the reformulated gasoline drops by 2.2%, from 23.1% to 20.9%. Aromatics in conventional gasoline drops by 1.6%, from 31.6% to 30.0%.

benzene

In the summer cases, addition of HiTEC 3000 did not reduce benzene from the average maximum specification of 0.95% in reformulated gasoline nor from the historic maximum of 1.49% in conventional gasoline. In the winter, however, benzene is not at the maximum because more MTBE is blended due to the oxygenated gasoline requirement. Further, the higher RVP of gasoline allows more high octane

butane blending, which reduces the need for aromatic octanes, with concomitant benzene reduction. Our "reformulated" pool has a higher composite benzene limit because of the inclusion of oxygenated/unreformulated gasoline. Addition of HiTEC 3000 further reduced aromatics and benzene in the winter.

*other
properties*

There are negligible differences in olefin content of gasoline between cases. The sulfur limit is not binding, and there are some shifts from case to case. T90 is at or near the limit in all cases and is not significantly affected by HiTEC 3000.

*material
balance*

There is a substantial savings of imported crude oil in all of the HiTEC 3000 cases, compared to the corresponding base case. This savings is summarized in Table 1. Examination of the LP runs in detail reveals that most of this savings can be traced to reformer operations. Economic use of manganese octanes relieves the need for process octanes from the reformer, hence, reformer severity and feed rate are reduced, and reformer gasoline yield is improved. This increase in reformate yield is translated into a reduction in gasoline from crude. The decrease in crude also reduces residual yield.

The model was free to choose rates for Nigeria medium, United Kingdom Brent and Saudi Arabian heavy, medium and light crudes within practical limits. In most cases, the model chose to vary Saudi Arabian light between the base

and HiTEC 3000 cases, and all results are reported on this basis to be conservative. In a summer maximum reformulation with HiTEC 3000 case, however, the model switched between Saudi Arabian medium and light. Based on these results, annual U.S. crude savings are projected to be 5 MBPD higher. We believe this higher crude savings level is realistic, but did not take credit for it.

The increased yield of reformate comes at the expense of plant fuel gas production. There are also offsetting reductions in fuel requirement at the reformer, crude distillation and other units. The difference is made up by domestic natural gas.

Use of HiTEC 3000 reduces the need for aromatic octanes. This reduces the heat of combustion of the gasoline. We have increased the gasoline volume to maintain constant vehicle miles traveled.

economic
HiTEC 3000
use

The economic use of HiTEC 3000 in each grade of gasoline is balanced against the alternate cost of octanes from processing. These balanced octane costs are shown in Table 3. The resulting manganese levels in each grade of gasoline for all of the HiTEC 3000 cases are shown in Table 4.

EMISSIONS RESULTS

bases and assumptions

Use of HiTEC 3000 reduces refinery emissions of NO_x , CO, particulates, SO_x and CO_2 . HiTEC 3000 provides up to 0.9 octane in conventional and reformulated gasoline. This allows refinery processing severity to decrease, which in turn lowers refinery energy demand. Since emissions are directly related to fuel usage, they are reduced as well. The units most affected by HiTEC 3000 usage in this way are the catalytic reformer and the fluid catalytic cracker. Table 2 shows the estimated emissions reductions which are achieved.

general

Petroleum refineries operate under air permits which regulate their emission of the following four "criteria" pollutants:

- Nitrogen oxides – NO_x ;
- Carbon monoxide – CO;
- Total suspended particulates – TSP; and
- Sulfur dioxide – SO_2 .

These are called criteria pollutants because a National Ambient Air Quality Standard (NAAQS) has been set for each under the Clean Air Act. Carbon dioxide (CO_2) is not a criteria pollutant, but it has also been addressed in this report because of possible detrimental environmental, or "greenhouse", effects attributed to it.

A typical air permit sets limits on the total plant emissions of the criteria pollutants and also usually designates maximum allowable emissions levels for specific point sources. State reporting requirements can be on an annual, quarterly, or

even monthly basis. In some cases, continuous emissions monitors (CEMs) are required on major emissions sources, and in those situations, the actual emissions can be measured quite accurately. In most cases, however, particularly with fired process heaters and steam boilers, CEMs do not exist, and emissions have to be calculated using various methods. These methods can all be translated to a relationship between mass of emissions released to unit of fuel fired (pounds/million BTU).

*nitrogen
oxides*

Two nitrogen oxide compounds, nitrogen oxide (NO) and nitrogen dioxide (NO₂), are considered significant air pollutants and health hazards, even at low concentrations. They are involved in the formation of both smog and acid rain. The term NO_x is commonly used to refer to the sum of NO and NO₂.

Petroleum refineries are a major source of NO_x emissions. They are formed during the high temperature combustion of fuel with air, which results in direct reaction of atmospheric nitrogen with atmospheric oxygen to form NO_x. NO is the primary oxide of nitrogen formed within the fired heaters. NO₂ is formed when the flue gases exit to the atmosphere, where the NO is further oxidized to NO₂ in the presence of an abundance of oxygen at lower temperatures. Basic variables involved in the formation of NO_x during fuel combustion are temperature, residence time and percent of

theoretical combustion air, with increases in each of the variables resulting in increased NO_x formation.

Various NO_x control techniques exist, such as two-stage combustion, off-stoichiometric firing, flue gas recirculation and modified burner configuration. All of these techniques are aimed at reducing one or more of the three basic kinetic variables. TM&C experience indicates that, with existing equipment, refinery fired heaters emit NO_x at an average overall rate of 0.12 pounds per million BTU, which is equal to the EPA limit of 0.12 pounds per million BTU for new fired heater installations. This current limit applies to furnaces which have been built since the early 1980s, and it replaced an earlier limit which was 0.2 pounds per million BTU. In the future, this limit for new installations is expected to continue to decrease. The Los Angeles area already requires new installation NO_x emission rates below 0.06 pounds per million BTU. The EPA may lower their NO_x limit to 0.03 pounds per million BTU for new installations by 1992.

*sulfur
dioxide*

SO_2 emissions have received particular attention recently in the media and the legislative arena, as they are probably a major cause of acid rain (along with NO_x). SO_2 emissions are caused by the reaction of sulfur in the fuel with oxygen made available during combustion. The level of SO_2 emission is directly related to the amount of sulfur in the fuel, independent of combustion conditions. The power-generating industry, which uses significant amounts of high

sulfur coal as fuel, is the primary source of industrial SO_2 emissions in the U.S. By comparison, the petroleum refining industry, due to its reliance on low sulfur content gas plus some low sulfur liquid fuels, is a relatively small generator of SO_2 emissions in the U.S.

To determine an emission factor for SO_2 from refinery fired heaters, it is necessary to estimate the average sulfur content of the fuel used at refineries. Current EPA regulation limits the gaseous fuels to a sulfur content of 0.1 grain/SCF, which equals about 160 ppm. Our experience with refinery operations indicates that the current overall average is far below this limit, at an estimated 25 ppm. This translates to an emission factor of 0.002 pounds of SO_2 per million BTUs of gas fired.

Refinery liquid fuel is also low sulfur, but it is significantly higher in sulfur content than gas fuels, resulting in a much higher SO_2 emission factor than gas. Our estimate of the average sulfur content of fuel oil burned in refineries is 0.3 weight %, with a corresponding emission factor of 0.33 pounds of SO_2 per million BTU fired.

In addition to refinery heater stacks, SO_2 is also emitted by sulfur plants located in refineries. We have estimated that 99% of the sulfur processed at refinery sulfur plants is recovered as liquid sulfur, with the remaining 1% emitted as SO_2 .

*carbon
monoxide*

Automobiles are the major source of carbon monoxide (CO) pollution, a major component of smog, with the refineries again a relatively minor contributor. CO is formed from incomplete combustion of hydrocarbons and can be significantly reduced by modifying combustion conditions. From flue gas analysis data at various refineries, we estimate that the average refinery fired heater has a CO concentration of about 50 ppm in the fuel gas. This translates to an emission factor of 0.04 pounds of CO per million BTU of fuel fired.

particulates

Particulate emissions, which are also a contributor to smog, are primarily a function of the ash content of the fuel, with combustion conditions also playing a role. The power industry is the primary industrial generator of particulates due to its reliance on high ash solid fuels. The refining industry is a much smaller contributor because of its use primarily of gaseous fuels and some liquids. We estimate an emission factor of 0.015 pounds of particulates per million BTU of fuel fired at the average refinery fired heater or boiler.

*carbon
dioxide*

Carbon dioxide (CO₂) is a natural and necessary component of the atmosphere and is not a hazard to human health. However, it has been theorized that increased levels of CO₂ in the atmosphere can be detrimental to the environment, particularly by causing what is known as the greenhouse effect.

Carbon dioxide and water are produced when hydrocarbons are burned. Since it is a primary product in the combustion of hydrocarbons, the amount of CO₂ produced varies only with the quantity and type of hydrocarbon used. Control is possible only by decreasing firing rates.

A CO₂ emission rate can be determined by the estimated average carbon number of fuel burned at refinery furnaces. TM&C estimates an average refinery emission factor of 125 pounds of CO₂ per million BTU of fuel fired.

TABLE 1
U.S. CRUDE OIL SAVINGS
STUDY OF EFFECTS OF HITEC 3000 USE
 (thousand barrels per day)

	<u>Summer</u>	<u>Winter</u>	<u>Annual</u>
Minimum Reformulated Gasoline	142	28	85
Maximum Reformulated Gasoline	70	24	47

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TABLE 2
REFINERY EMISSIONS CHANGES
1995 CASE RESULTS - ESTIMATED U.S.
MANGANESE CASE DECREASE FROM BASE CASE
STUDY OF EFFECTS OF HITEC 3000 USE
(tons per year)

	<u>Summer</u>	<u>Winter</u>	<u>Annual</u>
<u>Minimum Reformulated Gasoline</u>			
NO _x	4,390	1,010	2,700
CO	3,580	720	2,150
Particulates	3,330	630	1,980
SO _x	6,370	1,150	3,760
CO ₂ (thousands)	2,860	750	1,800
<u>Maximum Reformulated Gasoline</u>			
NO _x	2,560	740	1,650
CO	1,970	460	1,220
Particulates	1,790	370	1,080
SO _x	4,080	650	2,360
CO ₂ (thousands)	1,760	590	1,180

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TABLE 3
OCTANE IMPROVEMENT COSTS⁽¹⁾
1995 CASE RESULTS - IIIC
STUDY OF EFFECTS OF HITEC 3000 USE
(¢ per octane number barrel)

	<u>Summer</u>	<u>Winter</u>
<u>Minimum Reformulated Gasoline</u>		
Without HiTEC 3000	30	12
With HiTEC 3000	17	10
<u>Maximum Reformulated Gasoline</u>		
Without HiTEC 3000	21	10
With HiTEC 3000	14	9

⁽¹⁾Shadow costs for very small changes; not applicable for significant changes

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TABLE 4
HITEC 3000 USE - RESULTS
STUDY OF EFFECTS OF HITEC 3000 USE

	HITEC 3000, mg Mn/Gal.			
	<u>Minimum Reformulated</u> <u>Summer</u>	<u>Winter</u>	<u>Maximum Reformulated</u> <u>Summer</u>	<u>Winter</u>
<u>Conventional</u>				
Regular	31	10	15	10
Midgrade	20	5	15	5
Premium	23	5	15	5
Pool	28	8	15	8
<u>Reformulated/Oxygenated</u>				
Regular	25	10	15	6
Midgrade	20	5	15	5
Premium	10	5	15	5
Pool	21	8	15	6
<u>Total Gasoline Pool</u>	26	8	15	7

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TABLE A-1

BASIS AND ASSUMPTIONS

STUDY OF EFFECTS OF HITEC 3000 USE

- Use the Turner, Mason & Company (TM&C) linear programming (LP) model of PADD III conversion refineries. PADD III gasoline production is about 45% of total U.S. production.
- Run 1995 summer and winter cases with minimum and maximum opt-in as estimated by DOE.

	% Reformulated/Oxygenated				Oxygen %
	Minimum		Maximum		
	Summer	Winter	Summer	Winter	
RFG @ 2.1% O ₂	25.3	8.6	63.3	31.2	2.1
RFG @ 2.7% O ₂	-	16.7	-	32.1	2.7
Oxygenated @ 2.7% O ₂	-	20.0	-	4.6	2.7
Conventional	<u>74.7</u>	<u>54.7</u>	<u>36.7</u>	<u>32.1</u>	0.0
	100.0	100.0	100.0	100.0	-

- As specified by DOE, assume no growth in gasoline (or other products) demand from 1990 to 1995. This is a very conservative assumption.
- Assume octanes by grade are the same in 1995 as in 1990. Reformulated/oxygenated gasoline is the same octane as the corresponding conventional gasoline.
- As specified by DOE, conservatively assume that the 1990 gasoline grade ratio applies to 1995 except for leaded gasoline. Prorate 1990 leaded gasoline to unleaded grades to maintain constant marketed pool octane number.
- Reid vapor pressure (RVP) for the summer cases reformulated gasoline will be set at EPA average limits of 8.0 psi for area C and 7.1 for area B. Conventional gasoline will be at Phase II levels of 9.0 and 7.8 psi less a compliance margin of 0.3 psi. Winter RVP will be set at 1990 levels. These will be averaged according the PADD III supply patterns.
- Benzene level in reformulated gasoline will be set at 0.95 volume % average as recommended in EPA's Reg-Neg process.

- Aromatics level in reformulated gasoline will be limited to an average of 25% with no compliance margin.
- Reformulated gasoline will have no increase in olefins, sulfur and T90 from 1990 levels.
- Conventional gasoline will have no increase in benzene, aromatics, olefins, sulfur and T90 from 1990 levels.
- Table A-2 shows the 1990 average supply and disposition of crude oil and petroleum products for the U.S. Corresponding information for PADD III is shown in Table A-3. The seasonality of PADD III refining production of major products is shown in Table A-4. PADD III production will be allocated between simple refineries and the IIIC model conversion refineries.
- Development of PADD III 1990 gasoline production ratios is presented in Tables A-5, A-6 and A-7.
- NIPER data for summer and winter gasolines are shown in Tables A-8 and A-9. Data from the comprehensive 1989 NPRA survey are shown in Table A-10. The NPRA survey represents actual production at the refineries included in the TM&C LP model of PADD III conversion refineries.
- The NIPER data presented in Table A-8 indicate that $(R+M)/2$ octane numbers increased slightly from 1989 to 1990. Adjust the PADD III survey data in Table A-10 as follows:

	1989 <u>Survey</u>	<u>Increase</u>	1990 <u>Specifications</u>
Unleaded Regular	87.2	0.2	87.4
Unleaded Midgrade	89.1 [°]	0.1	89.2
Unleaded Premium	92.7	0.2	92.9

[°] Based on NIPER increase over unleaded regular.

Unleaded premium gasoline produced in PADD III has a higher octane number than the U.S. average because PADD III supplies gasoline to the East Coast where marketed premium gasoline octanes are higher than average. Winter gasolines have essentially the same octane numbers as summer gasolines, as shown in Tables A-8 and A-9

- Octane response to HiTEC 3000 is dependent on aromatic content, clear octane number and sensitivity (the difference between research and motor octane). Gains range from 0.6 to 0.9 octane for 1/32 gram manganese per gallon (31.25 mg Mn/gallon). The octane response curve for each grade of gasoline was approximated by straight lines covering increments of 5 mg Mn/gallon.
- Use TM&C pricing based on recent history prior to the Persian Gulf war. Based on the consensus outlook of numerous forecasts, we selected a \$20-per-barrel price for West Texas Intermediate crude.
- Assume the existing capacity plus current construction is adequate for the 1995 case exclusive of distillate desulfurization and gasoline reformulation processes.
- Allow investment over base for reformulated gasoline facilities with no HiTEC 3000; allow HiTEC 3000 with no further investment and no capital charge on reformulation processes.
- Adjust gasoline demand to account for the lower heat of combustion caused by introduction of oxygenates, lowering of aromatic content and lowering of gasoline 90% boiling point. Use an "R" factor that indicates gasoline requirements will go up 0.8% for every 1.0% decrease in the energy content of gasoline. This factor has been accepted by EPA in recent studies of vapor pressure reduction and other regulations.

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TABLE A-2

U.S. SUPPLY AND DISPOSITION OF PETROLEUM - 1990

STUDY OF EFFECTS OF HITEC 3000 USE

Table 3. U.S. Daily Average Supply and Disposition of Crude Oil and Petroleum Products, 1990
(Thousand Barrels per Day)

Commodity	Supply				Disposition				
	Road Production	Refinery Production	Imports	Unaccounted For Crude Oil ^a	Stock Change ^b	Crude Losses	Refinery Inputs	Exports	Products Supplied ^c
Crude Oil	7,398	-	8,084	280	-13	(d)	13,440	160	24
Natural Gas Liquids and LRGs	1,598	458	187	-	43	-	437	41	1,703
Petroleum Res	308	-	8	-	-7	-	175	2	148
Liquid Petroleum Gases	1,290	488	188	-	48	-	283	40	1,556
Ethane/Ethylene	477	18	7	-	-11	-	(d)	(d)	510
Propane/Propylene	474	404	115	-	48	-	(d)	23	917
Normal Butane/Butylene	148	87	50	-	7	-	137	12	110
Isobutane	151	11	18	-	5	-	188	0	18
Other Liquids	60	-	470	-	-11	-	713	8	-145
Other Hydrocarbons/Alcohols	60	-	(d)	-	2	-	70	0	0
Unrefined Oil	-	-	413	-	-31	-	607	0	-174
Motor Gasoline Blend, Comp	-	-	62	-	7	-	27	0	29
Aviation Gasoline Blend, Comp	-	-	0	-	(d)	-	(d)	0	(d)
Refined Petroleum Products	-	14,773	1,491	-	112	-	-	707	18,463
Refined Motor Gasoline	-	1,623	342	-	10	-	-	95	7,235
Landed	-	523	1	-	-31	-	-	0	325
Unlanded	-	1,100	341	-	31	-	-	48	6,910
Refined Aviation Gasoline	-	29	(d)	-	-1	-	-	0	24
Jet Fuel	-	1,420	103	-	31	-	-	43	1,522
Kerosene-Type	-	170	0	-	-1	-	-	4	182
Kerosene-Type	-	1,251	103	-	31	-	-	39	1,340
Kerosene	-	48	9	-	1	-	-	3	43
Diesel Fuel Oil	-	2,825	270	-	73	-	-	103	3,021
Residual Fuel Oil	-	680	504	-	13	-	-	211	1,229
Residual for Power, Food, Use	-	120	48	-	-1	-	-	5	182
Other Oil for Power, Food, Use	-	237	103	-	(d)	-	-	21	353
Special Residuals	-	68	11	-	(d)	-	-	10	83
Lubricants	-	100	12	-	-4	-	-	20	184
Waxes	-	17	1	-	(d)	-	-	2	18
Petroleum Cokes	-	582	2	-	-4	-	-	220	363
Asphalt and Road Oil	-	448	32	-	-6	-	-	3	483
Sol Gels	-	873	0	-	0	-	-	0	873
Miscellaneous Products	-	68	2	-	(d)	-	-	2	68
Total	10,000	14,773	1,010	280	187	(d)	14,800	887	10,000

^a Unaccounted for crude oil represents the difference between the supply and disposition of crude oil.

^b A negative number indicates a decrease in stocks and a positive number indicates an increase in stocks.

^c Products supplied to other countries for export, plus refinery production, plus imports, plus unaccounted for crude oil, minus stock change, minus crude losses, minus refinery losses, minus exports.

(d) = Less than \$100 barrels per day.

LRG = Liquid Petroleum Gases.

Note: Totals may not equal sum of components due to rounding.

Sources: Energy Information Administration (EIA) Form EIA-010 "Monthly Refinery Report," EIA-011 "Monthly Bulk Terminal Report," EIA-012 "Monthly Product Report," EIA-013 "Monthly Crude Oil Report," EIA-014 "Monthly Imports Report," EIA-015 "Monthly Natural Gas Liquids Report," and EIA-017 "Monthly Tank and Barge Movement Report." Domestic crude oil production from State conservation agencies and the Minerals Management Service of the U.S. Department of the Interior. Export data from the Bureau of the Census and Form EIA-010 "Monthly Refinery Report."

TABLE A-3

PADD III SUPPLY AND DISPOSITION OF PETROLEUM - 1990

STUDY OF EFFECTS OF HITEC 3000 USE

Table 9. PAD District III—Daily Average Supply and Disposition of Crude Oil and Petroleum Products, 1990
(Thousand Barrels per Day)

Commodity	Supply					Disposition				
	Field Production	Refinery Production	Imports by PAD District of Entry ^a	Unaccounted For Crude Oil ^b	Net Receipts	Stock Change ^c	Crude Losses	Refinery Inputs	Exports	Production Supplied ^d
Crude Oil	2,349	-	3,007	223	-1,402	-13	(0)	4,839	0	0
Natural Gas Liquids and LRGs	1,042	291	68	-	-63	0	-	223	10	1,023
Petroleum Plus	181	-	1	-	-8	-3	-	23	1	63
Liquid Petroleum Gases	855	291	63	-	-97	11	-	157	17	838
Ethane/Ethylene	324	11	3	-	-45	-15	-	(1)	0	439
Propane/Propylene	304	224	23	-	-118	18	-	(1)	11	407
Normal Butane/Butylene	72	64	23	-	3	8	-	64	5	63
Isobutane	118	12	12	-	-17	4	-	68	0	23
Other Liquids	62	-	203	-	-10	-10	-	483	0	-71
Other Hydrocarbons/Alcohol	82	-	0	-	0	(0)	-	91	0	0
Unrefined Oils	-	-	203	-	-10	-10	-	337	0	-85
Motor Gasoline Blend Comp.	-	-	10	-	-8	7	-	33	0	24
Aviation Gasoline Blend Comp.	-	-	0	-	0	(0)	-	(0)	0	(0)
Finished Petroleum Products	-	4,724	210	-	-3,101	34	-	-	349	3,423
Finished Motor Gasoline	-	3,123	16	-	-1,888	10	-	-	43	1,187
Lubricants	-	67	(1)	-	-10	-6	-	-	6	58
Unleaded	-	3,620	14	-	-1,098	15	-	-	37	1,131
Finished Aviation Gasoline	-	14	0	-	-7	(0)	-	-	0	7
Jet Fuel	-	749	17	-	-480	14	-	-	23	258
Kerosene-Type	-	67	0	-	-22	1	-	-	1	73
Kerosene-Type	-	640	17	-	-447	13	-	-	22	185
Kerosene	-	10	1	-	-12	(0)	-	-	5	3
Diesel Fuel Oil	-	1,304	2	-	-714	8	-	-	72	311
Residual Fuel Oil	-	323	20	-	-9	2	-	-	54	330
Paraffinized Feedstocks ^e	-	342	144	-	1	-1	-	-	17	470
Special Refinery	-	33	7	-	-12	1	-	-	6	21
Lubricants	-	101	(1)	-	-22	-3	-	-	9	73
Waxes	-	10	(1)	-	(1)	(0)	-	-	1	8
Petroleum Cuts	-	243	1	-	0	2	-	-	119	123
Asphalt and Road Oil	-	112	1	-	-10	-1	-	-	(0)	83
Silo Gas	-	303	0	-	0	0	-	-	0	303
Miscellaneous Products	-	13	(1)	-	-3	(0)	-	-	1	33
Total	4,430	7,843	4,433	223	-4,077	10	(0)	4,724	337	4,387

- ^a Receipts into PAD Districts in which the receipt occurs on the same item and not necessarily where the crude oil or product is produced and/or consumed.
- ^b Unaccounted for crude oil represents the difference between the supply and disposition of crude oil.
- ^c A negative number indicates a decrease in stocks and a positive number indicates an increase in stocks.
- ^d Production includes a credit to the production and refinery production and exports and unaccounted for crude oil, plus net receipts, minus stock change.
- ^e Net production minus refinery inputs minus exports.
- ^f Includes refinery and non-refinery production and exports and net receipts, minus stock change.
- (0) = Less than 500 barrels per day.
- LRG = Liquid Refinery Gas.
- Note: Totals may not equal sum of components due to rounding.
- Sources: Energy Information Administration (EIA) Reports (EIA-010, "Monthly Refinery Report," EIA-011, "Monthly Bulk Terminal Report," EIA-012, "Monthly Product Report," EIA-013, "Monthly Crude Oil Report," EIA-014, "Monthly Refinery Report," EIA-015, "Monthly Natural Gas Liquids Report," and EIA-017, "Monthly Total and Range Motor Gasoline Report." Domestic supply and production data from participating agencies and the Minerals Management Service of the U.S. Department of the Interior. Export data from the Bureau of the Census and from EIA-010, "Monthly Refinery Report."

TABLE A-4

PADD III PRODUCTION OF MAJOR PRODUCTS

SUMMER⁽¹⁾ VERSUS ANNUAL AVERAGE

STUDY OF EFFECTS OF HITEC 3000 USE

(% of annual)

	<u>1987</u>	<u>1988</u>	<u>1989</u>	<u>1990</u>	<u>Average</u>
Gasoline	102.4	100.5	103.4	101.7	102.0
Kerosene Jet Fuel	94.7	93.0	93.7	96.5	94.5
Distillate Fuel	94.7	97.7	97.4	101.0	97.7
Residual Fuel	98.6	98.7	93.9	97.0	97.1
Asphalt	126.9	119.7	117.7	118.6	120.7

⁽¹⁾ Second and third quartersGWM
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TABLE A-5
GASOLINE DEMAND GRADE RATIO
BY PADDs
STUDY OF EFFECTS OF HITEC 3000 USE
(%)

	PADD					U.S.
	I	II	III	IV	V	
<u>1990</u>						
Regular	0.2	3.4	2.3	22.1	15.4	4.8
Unleaded Regular	58.1	73.7	70.8	62.2	61.7	65.3
Unleaded Midgrade	14.5	8.8	10.4	2.4	1.8	9.6
Unleaded Premium	27.2	14.1	16.5	13.3	21.1	20.3

	U.S.					Outlook 1995
	1986	1987	1988	1989	1990	
Regular	31.8	23.7	17.4	10.0	4.8	-
Unleaded Regular	50.9	55.9	58.6	59.8	65.3	68.6
Unleaded Midgrade ^a	-	-	-	6.7	9.6	10.1
Unleaded Premium	17.3	20.4	24.0	23.5	20.3	21.3

^a Included in unleaded regular until 1989

Source: *Petroleum Marketing Monthly*, Table 47, annual average.

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TURNER, MASON & COMPANY
Consulting Engineers

TABLE A-6
MOVEMENTS OF GASOLINE
BETWEEN PADDS - 1990
STUDY OF EFFECTS OF HITEC 3000 USE
(MM barrels)

	Shipments from PADD					Total Receipts
	<u>I</u>	<u>II</u>	<u>III</u>	<u>IV</u>	<u>V</u>	
<u>Receipts</u>						
I	-	21.3	561.6	-	-	582.9
II	58.0	-	140.6	5.4	-	204.0
III	-	20.3	-	-	-	20.3
IV	-	10.7	-	-	-	10.7
V	<u>-</u>	<u>-</u>	<u>11.3</u>	<u>10.6</u>	<u>-</u>	<u>21.9</u>
Total Shipments	58.0	52.3	713.5	16.0	0	839.8
Total Receipts	<u>582.9</u>	<u>204.0</u>	<u>20.3</u>	<u>10.7</u>	<u>21.9</u>	<u>839.8</u>
Net Receipts						
MM Barrels	524.9	151.7	(693.2)	(5.3)	21.9	-
M Barrels/Day	1,438	416	(1,899)	(15)	60	-

Source: *Petroleum Supply Annual*, 1990, Table 32.

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TABLE A-7
PADD III GASOLINE PRODUCTION GRADE RATIO
STUDY OF EFFECTS OF HITEC 3000 USE
(%)

	1990				Exported	Total	Outlook 1995
	Destination PADD						
	I	II	III	V			
Regular	0.2	3.4	2.3	15.4	-	1.5	-
Unleaded Regular	58.1	73.7	70.8	61.7	100.0	65.2	66.2
Unleaded Midgrade	14.5	8.8	10.4	1.8	-	12.0	12.2
Unleaded Premium	<u>27.2</u>	<u>14.1</u>	<u>16.5</u>	<u>21.1</u>	<u>-</u>	<u>21.3</u>	<u>21.6</u>
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0
PADD III Refinery Supply, MB/D	1,539	385	1,131	31	39	3,125	-

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TABLE A-8
 SUMMER GASOLINE PROPERTIES(1)
 U.S. AVERAGE(2)
 STUDY OF EFFECTS OF HITEC 3000 USE

<u>Unleaded Regular</u>	<u>1989</u>	<u>1990</u>	<u>Delta</u>
Gravity, °API	58.2	58.2	0.0
Sulfur, Wt. %	0.033	0.037	0.004
Benzene, Vol. %	1.76	1.73	(0.03)
Octane Number			
Research	91.9	92.0	0.1
Motor	82.5	82.8	0.3
(R+M)/2	87.2	87.4	0.2
RVP, psi	9.1	8.7	(0.4)
20 V/L, °F	137	140	3
Distillation, °F			
IBP	94	93	(1)
10%	123	125	2
50%	211	212	1
90%	343	346	3
EP	414	417	3
<u>Unleaded Midgrade</u>			
Gravity, °API	57.1	57.4	0.3
Sulfur, Wt. %	0.029	0.028	(0.001)
Benzene, Vol. %	1.65	1.75	0.10
Octane Number			
Research	94.0	94.0	0.0
Motor	84.2	84.4	0.2
(R+M)/2	89.1	89.2	0.1
RVP, psi	9.2	8.7	(0.5)
20 V/L, °F	139	141	2
Distillation, °F			
IBP	93	93	0
10%	125	126	1
50%	219	216	(3)
90%	342	342	0
EP	416	415	(1)
<u>Unleaded Premium</u>			
Gravity, °API	55.3	55.5	0.2
Sulfur, Wt. %	0.011	0.013	0.002
Benzene, Vol. %	1.87	1.86	(0.01)
Octane Number			
Research	97.4	97.4	0.0
Motor	87.2	87.6	0.4
(R+M)/2	92.3	92.5	0.2
RVP, psi	9.1	8.7	(0.4)
20 V/L, °F	142	144	2
Distillation, °F			
IBP	93	92	(1)
10%	128	129	1
50%	228	227	(1)
90%	332	332	0
EP	406	405	(1)

(1) NIPER data

(2) Excluding high altitude gasoline

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TABLE A-9
 SUMMER VERSUS WINTER GASOLINE PROPERTIES(1)
 U.S. AVERAGE(2)
 STUDY OF EFFECTS OF HITEC 3000 USE

<u>Unleaded Regular</u>	<u>Winter 1989-90</u>	<u>Summer 1989</u>	<u>Delta</u>
Gravity, °API	62.2	58.2	4.0
Sulfur, Wt. %	0.041	0.033	0.008
Benzene, Vol. %	1.63	1.76	(0.13)
Octane Number			
Research	91.7	91.9	(0.2)
Motor	82.6	82.5	0.1
(R+M)/2	87.2	87.2	0.0
RVP, psi	13.2	9.1	4.1
20 V/L, °F	116	137	(21)
Distillation, °F			
IBP	82	94	(12)
10%	104	123	(19)
50%	194	211	(17)
90%	334	343	(9)
EP	406	414	(8)
<u>Unleaded Midgrade</u>			
Gravity, °API	61.2	57.1	4.1
Sulfur, Wt. %	0.029	0.029	0.000
Benzene, Vol. %	1.53	1.65	(0.12)
Octane Number			
Research	93.9	94.0	(0.1)
Motor	84.5	84.2	0.3
(R+M)/2	89.3	89.1	0.2
RVP, psi	13.0	9.2	3.8
20 V/L, °F	117	139	(22)
Distillation, °F			
IBP	82	93	(11)
10%	106	125	(19)
50%	200	219	(19)
90%	329	342	(13)
EP	404	416	(12)
<u>Unleaded Premium</u>			
Gravity, °API	58.7	55.3	3.4
Sulfur, Wt. %	0.014	0.011	0.003
Benzene, Vol. %	1.74	1.87	(0.13)
Octane Number			
Research	97.3	97.4	(0.1)
Motor	87.4	87.2	0.2
(R+M)/2	92.4	92.3	0.1
RVP, psi	13.3	9.1	4.2
20 V/L, °F	119	142	(23)
Distillation, °F			
IBP	82	93	(11)
10%	106	128	(22)
50%	217	228	(11)
90%	325	332	(7)
EP	398	406	(8)

(1) NIPER data

(2) Excluding high altitude gasoline

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TABLE A-10
AVERAGE 1989 SUMMER GASOLINE PROPERTIES
AS PRODUCED BY PADD(1)
STUDY OF EFFECTS OF HITEC 3000 USE

	<u>PADD III</u>	<u>U.S. Total</u>
<u>Leaded Regular</u>		
Octane, (R+M)/2	89.1	88.4
Sulfur, ppm	330	383
Aromatics, Vol. %	28	28
Olefins, Vol. %	14	14
Benzene, Vol. % *	1.53	1.67
RVP, psi	9.1	9.2
ASTM Distillation		
10%	123	122
30%	164	161
50%	209	207
70%	262	258
90%	340	334
<u>Unleaded Regular</u>		
Octane, (R+M)/2	87.2	87.1
Sulfur, ppm	381	384
Aromatics, Vol. %	29	30
Olefins, Vol. %	15	14
Benzene, Vol. % *	1.46	1.54
RVP, psi	9.3	9.5
ASTM Distillation		
10%	119	119
30%	148	154
50%	207	205
70%	261	260
90%	344	339
<u>Unleaded Premium</u>		
Octane, (R+M)/2	92.7	92.5
Sulfur, ppm	141	143
Aromatics, Vol. %	38	38
Olefins, Vol. %	7	7
Benzene, Vol. % *	1.54	1.62
RVP, psi	9.8	9.6
ASTM Distillation		
10%	121	123
30%	164	174
50%	223	224
70%	270	269
90%	335	330
<u>Pool By Grades</u>		
Octane, (R+M)/2 - Clear	89.0	88.7
Sulfur, ppm	305	321
Aromatics, Vol. %	32	32
Olefins, Vol. %	12	11
Benzene, Vol. % *	1.49	1.58
RVP, psi	9.4	9.5
ASTM Distillation		
10%	120	120
30%	155	160
50%	212	210
70%	263	262
90%	342	336
<u>Component Pool</u>		
Aromatics, Vol. %	32	32
Olefins, Vol. %	13	13

(1) Based on 1989 NPRA survey data * Niper data.
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TABLE A-11
REFINERY PROCESS CAPACITIES BASIS
STUDY OF EFFECTS OF HITEC 3000 USE

- Start with all operable refineries in PADD III as of January 1, 1989 reported by DOE in the 1988 PSA.
- Exclude simple refineries that have no catalytic cracking nor hydrocracking.
- Exclude refineries that reported no inputs to DOE in 1988.
- Add refineries that have announced restarts and have actively begun the restart process.
- Delete refineries that have announced pending shutdowns. Deletion of some downstream equipment when indicated by announcement.
- Add process unit capacity that is under construction or completed since 1/1/89 according to *Hydrocarbon Processing* and *Oil & Gas Journal*.
- Include units at partially operating refineries. Do not include in refinery count if crude unit is idle (except for Valero at Corpus Christi).
- Add some 1/1/90 unit capacities indicated in NPRA survey not shown by published data.
- Assume following maximum utilizations of stream day capacities:

	IIIC	
	<u>2nd and 3rd Qtrs.</u>	<u>1st and 4th Qtrs.</u>
Crude	96	93
FCC/Coking	95	88
Hydrocracking	88	85
Dependent Downstream ⁽¹⁾	88	85
Other Downstream	95	92

⁽¹⁾ Units for which operation is dependent on simultaneous operation of other downstream units i.e. alkylation, polymerization, C₄ isomenzation, hydrogen and MTBE

Sulfur recovery maximum utilization of stream day capacities is: 66% in model IIIC

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TABLE A-12
REFINERY PROCESS UNIT CAPACITIES DETAIL
BASE(1) BEFORE REQUIRED ADDITIONS
STUDY OF EFFECTS OF HITEC 3000 USE
(MBPSD)

	<u>IIIC</u>	<u>Total</u>
Number of Refineries	44	202
<u>Feed Rate</u>		
Crude - Atmospheric	6,883.1	16,215.5
Crude - Vacuum	2,885.2	7,057.9
Catalytic Cracking	2,552.9	5,392.4
Hydrocracking	421.6	989.3
Hydrocracking (Low Conv)	105.4	247.2
Coking - Delayed	580.3	1,347.8
Coking - Fluid	36.5	199.7
Combined	616.8	1,547.5
Combined Coke, 400 #B	136.3	350.7
Thermal Cracking / Visbreaking	82.5	181.9
Solvent Deasphalting	164.5	307.5
Catalytic Reforming		
100 psi	778.1	1,216.9
200 psi	255.7	700.2
450 psi	709.6	2,034.3
Total	1,743.4	3,951.3
Hydrotreating		
Naphtha	1,800.3	4,081.5
Distillate	1,539.0	2,940.8
Heavy Gas Oil	763.4	1,830.2
Residuum	281.0	320.5
Reformate Fractionation(2)	505.2	841.5
Aromatics Extraction(2)	299.7	396.2
Toluene Hydrodealkylation	27.8	45.2
FCC Gaso Splitter*	628.2	1,500.5
<u>Product Rate</u>		
Alkylation	500.8	1,043.3
Polymerization	50.1	109.2
Isomerization - C5/C6	155.9	378.9
Isomerization - C4	23.7	64.2
Hydrogen, MMSCF/PSD	1,139.2	2,994.3
Hydrogen, FOE	57.9	152.3
Asphalt	163.6	800.2
Lube	111.9	228.9
Aromatics	209.9	277.4
MTBE	27.6	38.2
Sulfur, M/STPD	11.2	23.2

(1) 1/1/89 existing (DOE - PSA 1988) plus under construction or completed according to Hydrocarbon Processing and Oil and Gas Journal.

(2) Estimated from aromatics capacities

* Increased based on NPRA survey

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TABLE A-13
 PADD III SIMPLE REFINERY PRODUCTION
 STUDY OF EFFECTS OF HITEC 3000 USE
 (thousand barrels per day)

	<u>Summer</u>	<u>Winter</u>
Unleaded Regular Gasoline	30	29
Naphtha Jet Fuel	35	35
Kero Jet/Kero	11	12
Diesel Fuel, 0.25% Sulfur	47	49
Residual Fuel	20	21
Asphalt/Road Oil	24	16
Naphthas and specialties	16	16
Lube/Wax	19	19
Miscellaneous	<u>8</u>	<u>8</u>
 Total Products	 210	 205

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TABLE A-14

1995 ESTIMATED SPOT PRICING

PADD III - TM&C OUTLOOK⁽¹⁾

STUDY OF EFFECTS OF HITEC 3000 USE

	<u>Summer</u>	<u>Winter</u>
<u>Major Products, ¢/G</u>		
Unleaded Regular	60.0	56.0
Unleaded Premium	66.0	62.0
Jet/Kerosene	53.5	60.5
Distillate Fuel (0.25% Sulfur)	51.0	56.0
Distillate Fuel (0.05% Sulfur)	54.0	59.0
Bunker Fuel, \$/B	12.00	12.00
<u>Major Crudes, \$/B</u>		
Domestic - WTI	20.00	20.00
- WTS	18.00	18.00
- ANS	17.20	17.20
Foreign - UK Brent	19.80	19.80
- Nigeria Medium	20.20	20.20
- Dubai	17.85	17.85
- Saudi Light	17.95	17.95
- Saudi Heavy	16.50	16.50
<u>Other</u>		
MTBE, ¢/G	95.0	100.0
Methanol, ¢/G	60.0	60.0
Isobutane, ¢/G	40.0	40.0
Normal Butane, ¢/G	32.0	36.0
Propane, ¢/G	25.0	27.0
Natural Gas, \$/MMBTU	2.05	2.05
Natural Gas, \$/FOEB	12.92	12.92
Coke - <3% Sulfur \$ 400#/B	5.00	5.00

⁽¹⁾ Based on constant 1991 dollars for major products and crudes

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TABLE A-15
GASOLINE SPECIFICATIONS - 1995
STUDY OF EFFECTS OF HITEC 3000 USE

	Summer		Winter			
	<u>Reformulated Gasoline</u>	<u>Conventional</u>	<u>Reformulated Gasoline</u>	<u>Reformulated/ Oxygenated</u>	<u>Oxygenated</u>	<u>Conventional</u>
Oxygen, Vol %, Minimum	2.1	-	2.1	2.7	2.7	-
Benzene, Vol % Maximum	0.95	1.49	0.95	0.95	1.36	1.36
Aromatics, Vol % Maximum	25.0	31.6	25.0	25.0	28.7	28.7
Olefins, Vol %, Maximum	13.2	13.2	11.9	11.9	11.9	11.9
Sulfur, ppm, Maximum	305	305	365	365	365	365
T90, °F, Maximum	342	342	333	333	333	333
RVP, psi, Maximum	7.4	7.9	12.5	12.5	12.5	12.5

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TABLE B-1
 REFINERY RAW MATERIALS INPUT RATES DETAIL
 IIIC 1995 SUMMER BASE(1) RESULTS - MBPCD
 STUDY OF EFFECTS OF HITEC 3000 USE

	<u>Minimum Reformulated</u>		<u>Maximum Reformulated</u>	
	<u>Summer</u>	<u>Winter</u>	<u>Summer</u>	<u>Winter</u>
Domestic Crudes	2,164	2,164	2,164	2,164
Foreign Crudes	<u>4,291</u>	<u>3,709</u>	<u>4,025</u>	<u>3,590</u>
Subtotal Crudes	6,455	5,873	6,189	5,754
Natural Gasoline		47	6	53
Reformate, 100 RONC	(72)	(72)	(72)	(72)
Naphtha	2	7	2	7
Vacuum Gas Oil	231	231	231	231
Vacuum Resid	14	14	14	14
Normal Butane	85	238	86	247
Isobutane	63	37	66	32
MTBE	38	154	182	238
Propane	9	9	9	9
Natural Gas Feed to H2, FOE	20	20	20	21
Methanol	<u>20</u>	<u>17</u>	<u>19</u>	<u>16</u>
Total Input	6.865	6.575	6.752	6.551
Natural Gas for Fuel, FOE	134	172	161	185

(1) Without HITEC 3000

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TABLE B-2
REFINERY PRODUCT RATES DETAIL
IIC 1995 SUMMER BASE(1) RESULTS - MBPCD
STUDY OF EFFECTS OF HITEC 3000 USE

	<u>Minimum Reformulated</u>		<u>Maximum Reformulated</u>	
	<u>Summer</u>	<u>Winter</u>	<u>Summer</u>	<u>Winter</u>
<u>Motor Gasolines</u>				
Unleaded Regular	1,548	1,095	761	644
Unleaded Intermediate	290	205	142	121
Unleaded Premium	512	362	252	213
Reformulated Regular	536	930	1,337	1,391
Reformulated Intermediate	100	174	250	260
Reformulated Premium	<u>177</u>	<u>308</u>	<u>442</u>	<u>460</u>
Total Gasoline	3,163	3,074	3,184	3,089
 Aviation Gasolines	 14	 14	 14	 14
Naphtha Jet	62	62	62	62
Kero Jet/Kerosene	634	693	634	693
Distillate Fuels - 0.05% Sulfur	1,019	1,067	1,019	1,067
Distillate Fuels - 0.25% Sulfur	208	218	208	218
 <u>Residual Fuels</u>				
< 0.3% Sulfur	8	9	8	9
0.7 - 1.0% Sulfur	45	48	45	48
1.0 - 2.0% Sulfur	151	160	151	160
> 2.0% Sulfur	<u>187</u>	<u>148</u>	<u>112</u>	<u>128</u>
Subtotal	391	365	316	345
 Asphalt/Road Oil	 111	 73	 111	 73
Marketable Coke - 400 ^o	172	160	172	160
Benzene	29	21	29	21
Toluene	10	19	10	20
Xylene	36	36	36	36
Special Naphtha/Miscellaneous	87	87	87	87
Petrochem Naphtha	46	46	46	46
Lubes/Wax	92	92	92	92
Petrochem Gas Oil	187	187	187	187
Carbon Black Feed	39	39	39	39
Propene	66	66	66	66
Butanes/Butene	146	10	146	17
Propane	156	129	142	123
Plant Fuel	517	408	466	382
(Gain)/Loss	<u>(318)</u>	<u>(292)</u>	<u>(313)</u>	<u>(285)</u>
Total Products	6,865	6,575	6,753	6,551

(1) Without HITEC 3000

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TABLE C-1
RUN BASIS AND GASOLINE POOL PROPERTIES
1995 CASE RESULTS - IIIC - MINIMUM REFORMULATED GASOLINE
STUDY OF EFFECTS OF HITEC 3000 USE

	Summer		Winter	
	No Mn	With Mn	No Mn	With Mn
<u>Reformulated Limits*</u>				
Aromatics, %, Maximum	25.0	25.0	26.6	26.6
Ethers, %, Minimum	11.7	11.7	14.4	14.4
Olefins, %, Maximum	13.2	13.2	11.9	11.9
90% Point, °F, Maximum	342	342	333	333
Sulfur, ppm, Maximum	305	305	365	365
Reid Vapor Pressure, psi, Maximum	7.4	7.4	12.5	12.5
Benzene, %, Maximum	0.95	0.95	1.13	1.13
<u>Ethers, % Pool</u>				
Purchased	1.2	1.2	5.0	5.0
Manufactured	1.8	1.8	1.6	1.6
<u>Reformulated Requirement</u>				
% Base Pool	25.3	25.3	45.3	45.3
<u>Gasoline Pool Properties</u>				
(R+M)/2 Octane, Clear*	88.8	88.8	88.8	88.8
HiTEC 3000, mg Mn/gal		26		8
Aromatics, %	29.4	27.6	22.0	21.3
Ethers, %	3.0	3.0	6.6	6.6
Oxygen, %	0.5	0.5	1.2	1.2
Olefins, %	12.5	12.5	11.5	11.4
Benzene, %	1.35	1.35	1.08	0.99
Sulfur, wppm	303	273	265	279
Reid Vapor Pressure, psi*	7.8	7.8	12.5	12.5
Temperature at V/L = 20, °F	143	143	116	116
<u>Distillation</u>				
90%, °F	13	13	21	21
130°F, %	22	22	29	29
170°F, %	32	32	42	42
212°F, %	50	50	58	58
257°F, %	68	67	73	73
300°F, %	8	81	84	84
356°F, %	92	93	94	94
10%, °F	116	116	84	84
50%, °F	212	211	192	192
90%, °F	342	342	333	333
Heat Content, MBTU/G	113.6	113.6	110.7	110.7

* Input limit

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TABLE C-1A
 REFORMULATED GASOLINE POOL PROPERTIES
 1995 CASE RESULTS - IIIC - MINIMUM REFORMULATED GASOLINE
 STUDY OF EFFECTS OF HITEC 3000 USE

	Summer		Winter	
	No Mn	With Mn	No Mn	With Mn
<u>Reformulated Limits*</u>				
Aromatics, %, Maximum	25.0	25.0	26.6	26.6
Ethers, %, Minimum	11.7	11.7	14.4	14.4
Olefins, %, Maximum	13.2	13.2	11.9	11.9
90% Point, °F, Maximum	342	342	333	333
Sulfur, ppm, Maximum	305	305	365	365
Reid Vapor Pressure, psi, Maximum	7.4	7.4	12.5	12.5
Benzene, %, Maximum	0.95	0.95	1.13	1.13
<u>Reformulated Gasoline Pool Properties</u>				
(R+M)/2 Octane, Clear*	88.8	88.8	88.8	88.8
HiTEC 3000, mg Mn/gal		21		8
Aromatics, %	23.1	20.9	19.0	18.6
Ethers, %	11.7 *	11.7 *	14.4 *	14.4 *
Oxygen, %	2.1 *	2.1 *	2.6 *	2.6 *
Olefins, %	13.2 *	13.2 *	11.9 *	11.7
Benzene, %	0.95 *	0.95 *	0.96	0.83
Sulfur, wppm	305	305	224	285
Reid Vapor Pressure, psi*	7.4	7.4	12.5	12.5
Temperature at V/L = 20, °F	145	143	116	116
<u>Distillation</u>				
90%, °F	11	12	19	19
130°F, %	19	22	26	25
170°F, %	38	42	46	45
212°F, %	58	59	63	62
257°F, %	71	71	75	75
300°F, %	81	81	84	84
356°F, %	92	92	94	94
10%, °F	124	124	86	82
50%, °F	198	190	179	183
90%, °F	342 *	342 *	333 *	333 *
Heat Content, MBTU/G	111.5	110.9	108.9	109.0

* Input limit

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TABLE C-1B
CONVENTIONAL GASOLINE POOL PROPERTIES
1995 CASE RESULTS - IIIC - MINIMUM REFORMULATED GASOLINE
STUDY OF EFFECTS OF HITEC 3000 USE

	Summer		Winter	
	No Mn	With Mn	No Mn	With Mn
<u>Conventional Limits*</u>				
Aromatics, %, Maximum	31.6	31.6	28.7	28.7
Ethers, %, Minimum	-	-	-	-
Olefins, %, Maximum	13.2	13.2	11.9	11.9
90% Point, °F, Maximum	342	342	333	333
Sulfur, ppm, Maximum	305	305	365	365
Reid Vapor Pressure, psi, Maximum	7.9	7.9	12.5	12.5
Benzene, %, Maximum	1.49	1.49	1.36	1.36
<u>Conventional Gasoline Pool Properties</u>				
(R+M)/2 Octane, Clear*	88.8	88.8	88.8	88.8
HiTEC 3000, mg Mn/gal		28		8
Aromatics, %	31.6	30.0	24.5	23.7
Ethers, %				
Oxygen, %				
Olefins, %	12.3	12.3	11.1	11.2
Benzene, %	1.49	1.49	1.18	1.13
Sulfur, wppm	302	262	299	274
Reid Vapor Pressure, psi*	7.9	7.9	12.5	12.5
Temperature at V/L = 20, °F	143	143	116	116
<u>Distillation</u>				
90%, °F	14	14	22	23
130°F, %	23	22	31	32
170°F, %	31	29	38	39
212°F, %	48	47	53	54
257°F, %	67	66	71	71
300°F, %	81	81	84	84
356°F, %	92	93	94	94
10%, °F	114	114	89	84
50%, °F	216	219	202	199
90%, °F	342	342	333	333
Heat Content, MBTU/G	114.5	114.5	112.3	112.1

* Input limit

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TABLE C-2
REFINERY RAW MATERIAL AND PRODUCT RATE CHANGES
1995 CASE RESULTS - IIIC - MINIMUM REFORMULATED GASOLINE
MANGANESE CASE INCREASE OVER BASE CASE - MBPCD
STUDY OF EFFECTS OF HITEC 3000 USE

	<u>Summer</u>	<u>Winter</u>
<u>Raw Materials</u>		
Domestic Crude		
Foreign Crude	(64)	(12)
Subtotal Crudes	(64)	(12)
Natural Gasoline	1	
Naphtha		
MTBE	1	
Methanol		
NC4	11	3
IC4	3	(1)
Natural Gas to H2 Plant Feed	—	1
Total	(49)	(9)
Natural Gas to Fuel	27	6
<u>Products</u>		
Motor Gasolines	3	4
No 6 Bunker	(9)	(2)
Normal Butane		
Propane	(8)	(1)
Plant Fuel	(34)	(8)
Isobutane		
Marketable Coke		
Loss(Gain)	(1)	(2)
Total	(49)	(9)
<u>Gasoline Demand Increase (1)</u>		
Results	0.1	0.1
Target	0.1	0.1

(1) To maintain constant vehicle miles travelled

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TABLE D-1
RUN BASIS AND GASOLINE POOL PROPERTIES
1995 CASE RESULTS - IIIC - MAXIMUM REFORMULATED GASOLINE
STUDY OF EFFECTS OF HITEC 3000 USE

	Summer		Winter	
	No Mn	With Mn	No Mn	With Mn
<u>Reformulated Limits*</u>				
Aromatics, %, Maximum	25.0	25.0	25.3	25.3
Ethers, %, Minimum	11.7	11.7	13.5	13.5
Olefins, %, Maximum	13.2	13.2	11.9	11.9
90% Point, °F, Maximum	342	342	333	333
Sulfur, ppm, Maximum	305	305	365	365
Reid Vapor Pressure, psi, Maximum	7.4	7.4	12.5	12.5
Benzene, %, Maximum	0.95	0.95	0.98	0.98
<u>Ethers, % Pool</u>				
Purchased	5.7	5.7	7.7	7.7
Manufactured	1.7	1.7	1.5	1.5
<u>Reformulated Requirement</u>				
% Base Pool	63.3	63.3	67.9	67.9
<u>Gasoline Pool Properties</u>				
(R+M)/2 Octane, Clear*	88.8	88.8	88.8	88.8
HiTEC 3000, mg Mn/gal		15		7
Aromatics, %	26.2	25.1	20.7	20.2
Ethers, %	7.4	7.4	9.2	9.2
Oxygen, %	1.3	1.3	1.7	1.7
Olefins, %	12.3	12.4	10.8	10.8
Benzene, %	1.15	1.15	0.92	0.83
Sulfur, wppm	278	266	214	228
Reid Vapor Pressure, psi*	7.6	7.6	12.5	12.5
Temperature at V/L = 20 °F	144	144	116	116
<u>Distillation</u>				
90% °F	13	12	20	20
130°F, %	21	21	28	28
170°F, %	35	35	43	43
212°F, %	52	51	58	59
257°F, %	69	68	73	73
300°F, %	81	81	84	84
356°F, %	92	92	94	94
10% °F	120	121	88	84
50% °F	207	208	189	189
90% °F	342	342	333	333
Heat Content, MBTU/G	112.7	112.6	110.1	110.1

* Input limit

GWM
11/20/91

TABLE D-1A
REFORMULATED GASOLINE POOL PROPERTIES
1995 CASE RESULTS - IIIC - MAXIMUM REFORMULATED GASOLINE
STUDY OF EFFECTS OF HITEC 3000 USE

	Summer		Winter	
	No Mn	With Mn	No Mn	With Mn
Reformulated Limits*				
Aromatics, %, Minimum	25.0	25.0	25.3	25.3
Ethers, %, Minimum	11.7	11.7	13.5	13.5
Olefins, %, Maximum	13.2	13.2	11.9	11.9
90% Point, °F, Maximum	342	342	333	333
Sulfur, ppm, Maximum	305	305	365	365
Reid Vapor Pressure, psi, Maximum	7.4	7.4	12.5	12.5
Benzene, %, Maximum	0.95	0.95	0.98	0.98
Reformulated Gasoline Pool Properties				
(R+M)/2 Octane, Clear*	88.8	88.8	88.8	88.8
HITEC 3000, mg Mn/gal		15		6
Aromatics, %	24.1	22.8	19.1	18.6
Ethers, %*	11.7	11.7	13.5	13.5
Oxygen, %*	2.1	2.1	2.4	2.4
Olefins, %	13.2	13.0	10.5	11.0
Benzene, %*	0.95	0.95	0.85	0.82
Sulfur, ppm	298	244	272	196
Reid Vapor Pressure, psi*	7.4	7.4	12.5	12.5
Temperature at V/L, °F	145	144	116	116
Distillation				
90%, °F	12	12	20	19
130°F, %	20	20	27	26
170°F, %	37	38	45	45
212°F, %	54	55	61	62
257°F, %	69	69	74	75
300°F, %	81	81	84	84
356°F, %	92	92	94	93
10%, °F	123	125	84	82
50%, °F	203	200	183	182
90%, °F	342	342	333	333
Heat Content, MBTU/G	111.8	111.5	109.2	109.1

* Input limit

GWM
11/20/91

TABLE D-1B
CONVENTIONAL GASOLINE POOL PROPERTIES
1995 CASE RESULTS - IIIC - MAXIMUM REFORMULATED GASOLINE
STUDY OF EFFECTS OF HITEC 3000 USE

	Summer		Winter	
	<u>No Mn</u>	<u>With Mn</u>	<u>No Mn</u>	<u>With Mn</u>
<u>Conventional Limits*</u>				
Aromatics, %, Maximum	31.6	31.6	28.7	28.7
Ethers, %, Minimum	-	-	-	-
Olefins, %, Maximum	13.2	13.2	11.9	11.9
90% Point, °F, Maximum	342	342	333	333
Sulfur, ppm, Maximum	305	305	365	365
Reid Vapor Pressure, psi, Maximum	7.9	7.9	12.5	12.5
Benzene, %, Maximum	1.49	1.49	1.36	1.36
<u>Conventional Gasoline Pool Properties</u>				
(R+MY2 Octane, Clear)	88.8	88.8	88.8	88.8
HITEC 3000, mg Mn/gal		15		8
Aromatics, %	30.0	29.3	24.0	23.6
Ethers, %				
Oxygen, %				
Olefins, %	10.7	11.3	11.6	10.3
Benzene, %	1.49	1.49	1.08	0.85
Sulfur, wppm	244	305	105	297
Reid Vapor Pressure, psi	7.9	7.9	12.5	12.5
Temperature at V/L = 20, °F	142	143	117	116
Distillation				
90% °F	14	14	22	22
130°F, %	24	22	31	32
170°F, %	31	28	38	38
212°F, %	48	45	53	52
257°F, %	68	66	71	71
300°F, %	81	81	83	83
356°F, %	92	92	94	94
10% °F	116	113	89	90
50% °F	214	223	203	203
90% °F	342	342	334	332
Heat Content, MBTU/G	114.3	114.5	112.2	112.1

* Input limit

GWM
11/20/91

TABLE D-2
REFINERY RAW MATERIAL AND PRODUCT RATE CHANGES
1995 CASE RESULTS - IIIC - MAXIMUM REFORMULATED GASOLINE
MANGANESE CASE INCREASE OVER BASE CASE - MBPCD
STUDY OF EFFECTS OF HITEC 3000 USE

	<u>Summer</u>	<u>Winter</u>
<u>Raw Materials</u>		
Domestic Crude		
Foreign Crude	(32)	(11)
Subtotal Crudes	(32)	(11)
Natural Gasoline	1	1
Naphtha		
MTBE	1	
Methanol		2
NC4	7	
IC4	(3)	
Natural Gas to H2 Plant Feed	—	—
Total	(25)	(8)
Natural Gas to Fuel	13	3
<u>Products</u>		
Motor Gasolines	4	2
No. 6 Bunker	(7)	(3)
Normal Butane		
Propane	(3)	(1)
Plant Fuel	(18)	(5)
Isobutane		
Marketable Coke		
Loss(Gain)	(1)	(1)
Total	(25)	(8)
<u>Gasoline Demand Increase (1)</u>		
Results	0.1	0.1
Target	0.1	0.1

(1) To maintain constant vehicle miles travelled

CLM
11/20/91

29 May 1991

Correlation and Associated Emissions Tests

° In pursuit of a waiver to use its HiTEC® Fuel Additive, the Ethyl Corporation has conducted extensive and expensive tests over the past several years. During the process, Ethyl has pursued all issues raised by EPA, including the three listed below which were raised by EPA Ann Arbor activities during the past nine months:

- (1) Does MMT have the instantaneous effect of significantly increasing HC and particulate emissions?
- (2) Is diesel contamination in the particulates collection (dilution) tunnel used by EPA's Ann Arbor laboratories a factor in apparent increases of HC and particulates emissions noted by EPA when HiTEC® is used. (The tunnel was designed and primarily used for diesel engines.)
- (3) Are the testing procedures used by Ethyl-contracted laboratories vis a vis the procedures of EPA Ann Arbor a factor in apparent increases of HC and particulate emissions noted by EPA (Ann Arbor) when HiTEC 3000 is used.

° Ethyl has conducted several tests aimed squarely at instantaneous effects and has demonstrated such an effect does not exist. (EPA tests conducted at Ann Arbor, Aug-Oct 1990, on rental American vehicles also indicate no instantaneous effect.)

° As for the other two issues shown above, Ethyl sought EPA's advice and cooperation in designing and conducting particulates and correlation tests. Ethyl had been led to believe that these new tests would largely resolve the issues. Unfortunately, it now appears that may not be EPA's view. Time has become of considerable essence. Every additional test means more equipment, personnel, contractual agreements, and expense. It also bears noting that the scope of testing and analysis required and accomplished to date for HiTEC 3000 is without precedent regarding Additive waivers.

° Had Ethyl known that EPA Ann Arbor had embarked in early March 1991 on another series of tests involving its tunnel and gasoline types other than Ethyl's test fuel (Howell EEE), Ethyl could have conducted some concurrent, complementary testing. EPA records show that as early as 26-28 March, Ann Arbor tests indicated apparent MMT-related emissions problems with Indolene in a cleaned tunnel. The closeness with which the March-April Ann Arbor activities and data was guarded not only has resulted in yet another extension of time (and money), but, perhaps more unfortunately, raised questions of good faith. The attached chronology is illustrative.

JGS

29 May 1991

SEQUENCE OF RECENT EVENTS
REGARDING CORRELATION AND
ASSOCIATED EPA ANN ARBOR TESTS

- Aug-Oct 1990: EPA Ann Arbor tests of vehicles using Phillips Indolene gasoline and Ann Arbor's particulates collection tunnel showed apparent, significant increases of HC and particulate emissions attributable to HiTEC® 3000 (MMT).
- 31 October 1990: Deputy EPA Administrator Habicht promised Ethyl CEO full, open EPA consultations if Ethyl withdrew waiver request in order to resolve questions on health, HC and particulates.
- 1 November 1990: Ethyl waiver request withdrawn.
- Nov '90-Mar '91: Throughout the period, Ethyl expressed concern to EPA regarding conceivable diesel contamination effect of EPA Ann Arbor tunnel. Ethyl, coordinating plans with EPA, duplicated EPA's particulate tunnel apparatus at Southwest Research Institute (SWRI) -- and conducted an extensive test program to resolve the HC and particulate emissions issues.
- 13 March 1991: EPA Ann Arbor began a series of tests, using one test and one control car, to determine the effect of MMT (1/32 gm/gal) in Sun Oil Indolene gasoline on particulate and gaseous emissions. EPA's dilution tunnel was used initially in contaminated condition (diesel exhaust) and subsequently after being "cleaned". Ethyl was not informed.
- 13 March 1991: Week of 13 March:
- (1) Ethyl coordinated a meeting with the EPA Mobile Sources Staff (in Washington) for 26 March to brief on Ethyl's work to resolve the HC and particulate emissions increases reported by EPA Ann Arbor in October 1990. No mention of new tests.
 - (2) Ethyl reps and EPA Mobile Sources reps attended the EPA ORD Manganese Symposium at Research Triangle, N.C. at which several references were made to a conceivable particulates emissions problem. No mention of new EPA tests.
- 22 March 1991: Records show that EPA Ann Arbor cleaned the diesel tunnel.
- 26 March 1991: EPA Ann Arbor conducted first test run using "cleaned" tunnel.

- 26 March 1991: Ethyl reps briefed EPA Mobile Sources Staff in Washington. Provided handouts on (1) procedures and results from particulates and gaseous emissions tests at Southwest Research Institute (SWRI); and (2) analysis of EPA's particulate filters (Aug-Oct 1990 Tests) which demonstrated that "gasoline engine combustion products (could) not be the source of the material on the filters." Ethyl opening remarks were that the meeting was non-regulatory; Ethyl would be candid; Ethyl hoped EPA reps would be candid. Dr. Bruce Kolowich (EPA Ann Arbor; in charge of the "tunnel" testing) disagreed that the EPA tunnel had an effect, but stated that he didn't see a problem with the SWRI tests. The SWRI tests showed no significant particulate problems. At meetings's end, Ethyl and EPA agreed to proceed with tests to determine if procedures and results of Ethyl test labs and EPA Ann Arbor correlated. No EPA mention of tunnel tests underway at Ann Arbor.
- 01 April 1991: EPA Ann Arbor Correlation Manager Marty Reineman, in a telephone conversation with Ethyl's Don Hollrah (St. Louis), said that EPA might have some data to share on particulate emissions from the EPA tunnel that had been cleaned.
- 03 April 1991: Ethyl reps (led by Don Hollrah) met at Ann Arbor with EPA Correlation Manager Marty Reineman, Tom Schrodtt, and Bruce Kolowich. A draft correlation test protocol was prepared. In answer to a question by Don Hollrah, Reineman said that the particulate emission data mentioned on 1 April were not in presentable form. No such data were thereafter mentioned until 17 May 1991, 6 weeks later.
- 11 April 1991: Ethyl and EPA agreed to a protocol for correlation tests. EPA Washington overruled EPA Ann Arbor's recommendation to use Phillips Indolene (certification) gasoline and agreed to Ethyl's request to use Howell EEE (Certification) gasoline. Howell EEE had been the fuel for Ethyl's fleet tests. No mention of EPA's on-going tunnel tests at Ann Arbor.
- 18 April 1991: EPA (ORD, Research Triangle Park, NC) distributed draft "Summary Report of the Mn/MMT workshop" held week of 13 March. Report made no mention of or reference to the several comments made by participants during the concluding plenary session to the effect that the amounts of manganese which would be emitted from use of HiTEC 3000 would be of no public health consequence.

19 April 1991: First of two Ethyl correlation cars delivered to EPA Ann Arbor. First of three test runs 1 May. Third run 9 May. (Three weeks total time.) EPA stated delays caused by use of EPA tunnel for diesel engine tests (7 days); failed CO₂ analyzer (3 days); computer problem (1 day).

06 May 1991: Second of two Ethyl correlation test cars delivered to EPA. First of six test runs 13 May. Fourth run 22 May. (Fifth and sixth runs not be run until week of 27 May in order to permit "movement of equipment". EPA will have had the car 4 weeks in order to make 6 test runs.)

Note: EPA records show that on 23, 26 April and 9, 14 May 1991, EPA Ann Arbor conducted test runs (4 test days plus some necessary preparation time) for EPA's using Sun Oil Indolene. It appears that some of EPA's close-hold testing was at the expense of the Ethyl-EPA Correlation Program. (Also note 28 May entry.)

14 May 1991: A meeting was coordinated for a 28 May Ethyl briefing of EPA Washington Staff prior to Ethyl's refiling of the waiver petition. No EPA mention of new Ann Arbor testing.

15 May 1991: A request was made by Ethyl Washington Office to EPA's Barry Nussbaum (Washington) that EPA Ann Arbor expedite correlation testing in order that data could be available for 28 May briefing. No word on new Ann Arbor testing.

16 May 1991: In apparent response to the 15 May request to expedite correlation testing, EPA's Dave Kortum asked that Ethyl reps meet EPA's Dick Lawrence and Bruce Kolowich in Ann Arbor on 17 May to discuss procedures and test results. No other explanation.

17 May 1991: Ethyl reps met Lawrence and Kolowich at Ann Arbor. EPA test results with Sun Oil Indolene fuel, using a "dirty" and "clean" tunnel, were shown Ethyl reps for the first time. Results showed apparent, significant HC and particulate increases when MMT was used, regardless of tunnel cleanliness.

28 May 1991: Ethyl reps met EPA reps (including Dick Wilson, Mobile Sources Director) in Washington. Dick Lawrence provided data on commercial fuel EPA tests (using MMT) conducted 23, 24, 25 May. Test period coincided with period during which Ann Arbor said correlation tests could not be run because some "movement of equipment" had to be done. (As of 28 May, EPA (Ann Arbor) had Ethyl Buick test car since 6 May but had 3 correlation tests yet to run.)

ETHYL CORPORATION

GOVERNMENT RELATIONS

Lt. Gen. Jeffrey G. Smith, U.S.A. (Ret.)
Director of Government Relations

1155 Fifteenth Street, N.W., Suite 611
Washington, D.C. 20006
(202) 223-4411

7 June 1991

Ms. Mary T. Smith
Director, Field Operations & Support Division
Office of Mobile Sources
U.S. Environmental Protection Agency
Washington, D.C.

Dear Mary,

This letter responds to your 3 June request that Ethyl provide an automobile which both the EPA Ann Arbor Emissions Laboratory and one of Ethyl's contract emissions laboratories could test on Sun Oil certification fuel and, conceivably, on a commercial fuel. It also confirms my telephone conversation with Dave Kortum today.

Ethyl will provide two cars to EPA for further tests, but not the Buick currently at the EPA Ann Arbor Lab. In view of the successful correlation tests, Ethyl prefers not to return the Buick to SWRI (San Antonio). A return to SWRI would be necessary were the Buick committed to the additional tests you proposed.

Ethyl will provide two cars which Ethyl is currently testing with Sun Oil certification fuel ("indolene") provided by EPA. Barring unforeseen circumstances, Ethyl will deliver by 14 June a 1990 Ford Crown-Victoria to Ann Arbor -- and on 19 June a 1991 Chrysler LeBaron.

The Ford is being tested now at the ECS Labs (Livonia, MI) for gaseous emissions. The Chrysler (which was one of the two cars used in the correlation tests) is being tested now at SWRI for gaseous and particulates emissions with both Sun Oil "indolene" and Texaco premium (commercial grade) gasoline purchased in San Antonio. Results to date (see attachment) show no ill emissions effects from adding MMT.

Ethyl representatives (Don Hollrah and Denis Lenane) will contact EPA Ann Arbor early next week to make detailed arrangements.

Ethyl asks as a condition to the tests that Ethyl technical representatives be permitted full access to and observation of all aspects of experimental design for the tests (e.g., canisters, mileage accumulation, fans, vehicle preparation). In this regard, Ethyl recommends that any mileage accumulation be on roads, not

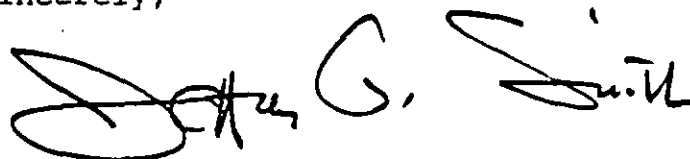
Ms. Mary T. Smith
7 June 1991
Page 2

dynamometers. Ethyl accepts that Ethyl reps may not be admitted to the dynamometer area.

Ethyl would appreciate being permitted to borrow and conduct tests using the 1991 Dodge Dynasty "Red Bruce". That is the car EPA Ann Arbor tested during March-May of this year.

Ethyl welcomes an open exchange with EPA of technical data pertaining to HiTEC® 3000, both before and after refiling Ethyl's waiver request for HiTEC 3000. However, as you know, a considerable amount of data has already been accumulated in support of Ethyl's petition. Results of Ethyl's most recent tests have added to that support. As events now stand, Ethyl does not consider it necessary to delay refiling pending completion of the additional tests discussed above.

Sincerely,

A handwritten signature in black ink, appearing to read "John G. Smith". The signature is stylized with a large, looping initial "J" and a distinct "S" at the end.

1 Enclosure

7 June 1991

RESULTS TO DATE OF ETHYL TESTS USING MMT (1/32gm/gal)
IN SUN OIL CERTIFICATION FUEL ("Indolene")
AND TEXACO PREMIUM (commercial) FUEL

Notes: Results shown are for tests thru 6/7/91. Estimated completion dates are 13 June at ECS Labs (Livonia, MI) and 17 June at SWRI (San Antonio). The Sun Oil fuel was provided by EPA Labs (Ann Arbor). Texaco fuel was purchased from a San Antonio retail dealer. All MMT emissions were measured with MMT fuel in the tank.

SWRI -- 1991 Chrysler LeBaron rental car (gm/mi)

	<u>HC</u>	<u>CO</u>	<u>NO_x</u>	<u>PM</u>
Howell EEE Clear	.36	1.83	.49	.009
Texaco Premium Clear	.52	2.42	.52	.007
Texaco Premium Clear	.47	2.30	.47	.008
Texaco Premium MMT	.46	2.49	.47	.007
Texaco Premium MMT	.46	2.42	.44	.007

(Note: Sun Oil "indolene" runs will follow Texaco runs.)

ECS -- 1990 Ford Crown-Vic rental Car (gm/mi)

	<u>HC</u>	<u>CO</u>	<u>NO_x</u>
Howell EEE Clear	.28	1.18	.69
Howell EEE Clear	.27	1.47	.62
Howell EEE MMT	.26	1.29	.62
Howell EEE MMT	.22	.64	.62
Howell EEE Clear	.23	1.28	.69
Howell EEE Clear	.25	.93	.78
Sun Oil Cert Clear	.23	.90	.66
Sun Oil Cert Clear	.24	.71	.66
Sun Oil Cert MMT	.23	.79	.70
Sun Oil Cert MMT	.21	.58	.73

ETHYL CORPORATION

GOVERNMENT RELATIONS

Lt. Gen. Jeffrey G. Smith, U.S.A. (Ret.)
Director of Government Relations

1155 Fifteenth Street, N.W., Suite 611
Washington, D.C. 20005
(202) 823-4411

8 July 1991

Ms. Mary T. Smith
Chief, Field Support & Operations Division
Office of Mobile Sources
U.S. Environmental Protection Agency
Washington, DC 20460

The following summarizes what I outlined to you on the telephone 3 July, and updates the emissions data on EPA's "Red Bruce" (1991 Dodge Dynasty) I provided.

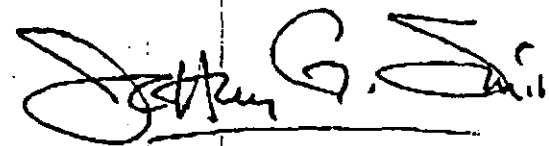
1) Sun Oil certification fuel blended with MMT by EPA Ann Arbor contains Freon 12 (a coolant). The fuel had a chloride content of 90ppm (equivalent of 200ppm of Freon 12). The fuel analyzed was taken from the tank of the Red Bruce upon its arrival at SWRI (San Antonio) from EPA Ann Arbor. In view of the likelihood of some Freon evaporating during the transport of the car, the chloride levels found by the Ethyl lab are considered conservative.

2) The chloride content of the fuel appears directly related to the matter collected by EPA personnel from the floor of EPA's test tunnel at Ann Arbor following EPA's March-May 1991 tests. That matter was 86% Ammonium Chloride, which coincides with the 80% level of chlorides found by Ethyl (and reported to you at EPA-Ethyl meeting, 26 March 1991) on the EPA particulates filter used during EPA's Aug-Oct 1990 tests of MMT effects.

3) An analysis of clear Sun Oil certification fuel provided Ethyl by EPA showed no chlorides present.

4) Attached are results of emissions tests conducted at SWRI 1-3 July, using the Red Bruce car, fueled with Sun Oil cert gasoline blended with MMT in one case by EPA Ann Arbor and in another by the ECS lab (under Ethyl contract). It can be noted that (1) the EPA-blended fuel produces markedly higher particulates levels than does the ECS-blended fuel; and (2) the SWRI lab was able to detect relatively high levels of particulates contrary to speculation heard at the EPA-Ethyl meeting, 24 June 1991.

5) As I observed to David Kortum on 27 June, all EPA emissions data generated in the Aug-Oct 1990 and March-May 1991 MMT effects tests may have been skewed by contaminated fuel.



cc: Mr. Richard D. Wilson
Director, Office of Mobile Sources, EPA

EMISSIONS TESTS CONDUCTED BY
SOUTHWEST RESEARCH LABORATORY, SAN ANTONIO, TX
USING EPA 1991 DODGE DYNASTY
KNOWN AS "RED BRUCE"

Fuels: "EPA" - Sun Oil Certification, blended with MMT by EPA.
"ECS" - Sun Oil Certification (provided by EPA), blended
with MMT by ECS lab.

<u>Date</u>	<u>Fuel</u>	<u>Cycle</u>	<u>HC</u>	<u>CO</u>	<u>NO_x</u>	<u>PM</u>	<u>Fuel Economy (mpg)</u>
7/1/91	EPA	FTP	0.44	3.09	0.64	0.044	21.0
7/2/91	EPA	FTP	0.49	3.07	0.58	0.042	21.0
7/3/91	ECS	FTP	0.41	2.92	0.52	0.015	20.84
7/3/91	ECS	HFET	0.05	0.80	0.12	0.016	33.8
7/3/91	ECS	NYCC	0.37	3.84	1.45	0.012	11.1

ETHYL DATA
(Provided 8 July 1991)

ETHYL CORPORATION

GOVERNMENT RELATIONS

Li. Gen. Jeffrey G. Smith, U.S.A. (Ret.)
Director of Government Relations

1105 Fifteenth Street, N.W., Suite 611
Washington, D.C. 20005
(202) 223-4411

9 July 1991

Ms. Mary T. Smith
Chief, Field Support & Operations Division
Office of Mobile Sources
U.S. Environmental Protection Agency
Washington, DC 20460

Below is another update on testing of the Red Bruce vehicle. Also, Ethyl's analysis of a batch of Sun Oil cert gasoline which EPA Ann Arbor blended with MMT on 1 July 1991 showed 760 ppm chloride; the chlorinated organic in the blend was again identified as Freon-12.

SWRI (San Antonio) tested EPA's Red Bruce car on July 3 and 8 using the EPA protocol and Sun Oil cert fuel blended with MMT by the ECS Lab (under Ethyl contract). Results:

<u>Date</u>	<u>Cycle</u>	<u>HC</u>	<u>CO</u>	<u>NO_x</u>	<u>Part.</u>	<u>F.E.</u>
7/3/91	FTP	0.41	2.92	0.52	0.015	20.8
7/3/91	HFET	0.05	0.80	0.12	0.016	33.8
7/3/91	NYCC	0.37	3.84	1.45	0.012	11.1

<u>Date</u>	<u>Cycle</u>	<u>HC</u>	<u>CO</u>	<u>NO_x</u>	<u>Part.</u>	<u>F.E.</u>
7/8/91	FTP	0.40	2.95	0.46	0.006	21.0
7/8/91	HFET	0.04	0.78	0.13	0.006	33.8
7/8/91	NYCC	0.39	5.10	1.24	0.011	11.3

Particulate emissions on July 3 decreased dramatically from those obtained by SWRI using the Red Bruce fueled with MMT & Sun gasoline blended by EPA. Gaseous emissions also decreased. SWRI making another run 9 July with Sun fuel plus MMT blended by ECS.



cc. Mr. Richard D. Wilson
Director, Office of Mobile Sources

ETHYL CORPORATION

GOVERNMENT RELATIONS

Lt. Gen. Jeffrey G. Smith, U.S.A. (Ret.)
Director of Government Relations

1155 Fifteenth Street, N.W., Suite 611
Washington, D.C. 20005
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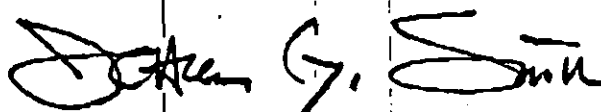
11 July 1991

Ms. Mary T. Smith
Office of Mobile Sources
Environmental Protection Agency
499 South Capitol Street
Third Floor
Washington, D.C.

Dear Ms. Smith,

- More info on fuel contaminantion.
- In late June, Ethyl obtained from EPA Ann Arbor some clear Sun Oil certification fuel for tests to be conducted at Ethyl contract labs. On 1 July, at Ethyl's request, EPA Ann Arbor blended some of that same clear fuel with MMT using EPA equipment. EPA chilled the blend for about 20 minutes in the EPA mixing cart which contains an internal refrigeration system.
- Ethyl analyzed both the clear Sun Oil fuel and the blend prepared by EPA using XRF and GC-MS techniques (sophisticated, recognized chemical analysis procedures).
 - 1) The clear fuel contained no Freon and no chlorides.
 - 2) The blend prepared by EPA contained 760 ppm chloride, the equivalent of 2.1 grams of chloride per gallon. The chlorinated organic in the blend was Freon-12 (a coolant). (The particulate samples given Ethyl by EPA to analyze were, it will be recalled, 80% and 86% chlorides.)
 - 3) The 760 ppm chloride contrasts to the 90 ppm of chloride found in the tank (MMT) fuel of the Red Bruce when received by SWRI from EPA. You'll recall that it is considered that some Freon-12 quite likely evaporated from the tank fuel when the car was en route from Ann Arbor to Texas.
- Our technical people tried unsuccessfully to reach Dr. Kolowich several times yesterday (10 July). Dr. Ter Haar is trying to reach Dick Lawrence today.

cc. Mr. Richard D. Wilson
Director, Office of Mobile Sources



ETHYL CORPORATION
Health and Environment Department

May 13, 1991

Donald R. Lynam, Ph.D.
Director, Air Conservation
and Industrial Hygiene

Ethyl Tower
451 Florida
Baton Rouge, LA 70801
504/388-8008
Cable Address: ETHYLEA
TELEX 526-441

Dr. J. Michael Davis
U.S. Environmental Protection Agency
Environmental Criteria and
Assessment Office
Research Triangle Park, NC 27711

Dear Dr. Davis:

I am providing general comments by the Ethyl Corporation on the draft Summary Report of the Mn/MMT Workshop held in Research Triangle Park, North Carolina on March 12-15, 1991, and individual comments on the summary of the conclusions of the Epidemiological Section in which I participated. Comments of other Ethyl participants (G. L. Ter Haar, B. F. Droy, D. E. Park, N. A. O'Malley, G. D. Pfeifer, and B. F. Fort) are being submitted individually.

I. Ethyl's General Comments on the Draft Summary Report

The draft summary report is misleading in two important respects. First, it suggests that the research recommendations were developed to address the issue of manganese from use of MMT. This was not the case. Many of the specialty sections, particularly the Health Specialty Sections, instructed participants to develop research recommendations to fill information gaps in our knowledge of manganese and health. In fact, these recommendations were, in most instances, made without any consideration of the level of incremental exposure to manganese from use of MMT. The health recommendations are therefore in the nature of a "wish list" of everything one would ever want to know about manganese and health. It is unlikely that the research proposed on manganese would be of value in assessing the health significance of the small incremental increase in exposure from use of MMT. The final report should clearly state that these research recommendations are addressed to general manganese toxicological concerns rather than the small incremental increase in manganese exposure from use of MMT.

In addition, the draft report completely omits any reference to the final Plenary Session of March 15 which brought together the three work groups (Health, Exposure, and Ecological/Transport) after some two days of separate discussions. This Plenary Session provided the opportunity to consider general health and ecological research recommendations in light of the exposures estimated with use of MMT. It is essential that the final report reflect the discussions of the final Plenary Session which tied together health and exposure.

-2-

To this end, we recommend that the description of the Plenary Session to be included in the final summary report should include the following points, all of which are based on our recollection of the Plenary Session and the transcript of the session which was included with Bill Brownell's letter of April 30, 1991 to Dr. Les Grant.

Point One -- The conclusions of the Exposure Group were critical to the Plenary Session discussion. The Exposure Group determined that considerable data and models were available to estimate the incremental airborne and soil manganese levels resulting from the use of MMT in gasoline. In the case of soil, the Group concluded there would be no additional significant exposure to children from ingestion as a result of using MMT in gasoline. The incremental increase of manganese in soil from automobile usage would be so small as to not be measurable when compared to levels naturally present in soil, of the order of a 1 ppm incremental increase in the present soil levels of 1,000 ppm following a lifetime of MMT use.

Point Two -- In the case of airborne manganese, the Exposure Group concluded that useful historical data existed to determine past and existing manganese levels and to estimate incremental increases of chronic adult human exposure to manganese from use of MMT in gasoline. A number of different models, including SCREAM Two (which is a very detailed model for estimating exposures for the South Coast of California -- specifically Los Angeles), the model based on historical lead data, and the model used in the EPA/ORD risk assessment, provide comparable estimates of airborne levels of manganese. Long term average urban airborne concentrations of manganese were estimated, by the various models, to be of the order of 0.05 ug/m^3 when MMT is used in all gasoline. This estimate includes a background or non-traffic related manganese level of 0.03 ug/m^3 .

Point Three -- The information from the Exposure Group on the small incremental increase in manganese exposure levels that would result from use of MMT helped to put the Health Group recommendations into perspective. Some participants in the Plenary Session indicated that if there is at present no problem with too much manganese (from all sources including food, soil, water, air, vitamin tablets, etc.), the small incremental increases of manganese from use of MMT would not make any difference. If, on the other hand, a health problem from too much manganese in the general population from these sources exists today, then efforts to reduce exposure to manganese would have to focus on the most significant sources of manganese (e.g., industrial point sources and/or vitamin tablets, etc.). No one supported the view that there is currently any health problem in the general population from exposure to manganese from food, air, soil, water, or vitamin tablets.

-3-

Point Four -- In light of this discussion, some participants questioned whether the infinitesimal incremental increases of manganese from use of MMT should trigger any additional health research needs. Others indicated that there are data needs on manganese and health, but questioned whether filling such data needs should be directed at the use of MMT.

Point Five -- Since incremental exposure to manganese from use of MMT is the determining factor concerning the need for additional health research relative to MMT use, clearly defining that incremental exposure was identified as the first priority. Data and information exist to significantly reduce uncertainty as to exposure levels from use of MMT. This information was summarized in the review by the Exposure Group presented at Friday's Plenary discussion and in presentations during the first-day exposure Plenary Session.

Point Six -- While the health group identified pharmacokinetic research as the health research of highest priority, the consensus of the work group was that inadequate understanding of exposure associated with use of the additive was the highest priority overall, in that the necessity and scope of any additional health research would depend upon the results of the exposure analysis.

In sum, we believe the existing exposure information and estimates are adequately verified and refined to reflect accurate estimates of exposures. The write-up of the Summary Report on Exposure Assessment Issues is far too conservative in that it suggests several additional studies, which are interesting, but are not critical to understanding levels of manganese in the air. In addition, the incremental exposures are so infinitesimal, and so much below the very conservative R_fC , that little, if any, health recommendations should be triggered.

II. Specific Comments on Epidemiological Specialty Section

With respect to the summary of the Epidemiological specialty session in which I participated, the discussion of possible study settings on page 19, particularly relating to MMT in Canada, should reflect concerns expressed about confounding exposures. Any subjects in microenvironments in Canada, in which relatively high exposure to manganese from MMT may exist, such as parking garage attendants, would also be exposed to high levels of other traffic related emissions, such as carbon monoxide, oxides of nitrogen, hydrocarbons, aromatics such as benzene, benzo-a-pyrene, and lead. These exposures would confound evaluations of health effects.

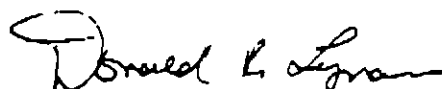
-4-

In addition, the point was made in the session and should be included in the write-up that the group did not think an epidemiological study of the general population in Canada would be feasible because the incremental increase in manganese exposure from MMT is so small.

The reference on page 18, last full paragraph, to Nogawa is misleading in that there are no data on ambient exposures to manganese in this study. Some rough estimates were made based on fallout information. This study has generally been disregarded by the scientific community because of its inadequacies. It is recommended that the reference to respiratory effects at low levels be omitted.

Thank you for providing us the opportunity to comment on the draft report. As suggested in Mr. Brownell's letter of April 30, once the summary report is revised to incorporate the final Plenary Session, ORD should distribute the new draft for comment.

Sincerely,



Donald R. Lynam, Ph.D., CIH, PE
Director, Air Conservation
and Industrial Hygiene

DRL:cr

Attachment

cc: Mr. F. W. Brownell

Dr. L. D. Grant

Dr. Judy Graham

Dr. G. L. Ter Haar

178DRL91

ETHYL CORPORATION
Health and Environment Department

Air Conservation

May 13, 1991

Ethyl Tower
451 Florida Street
Baton Rouge, LA 70801

Dr. J. Michael Davis
U.S. Environmental Protection Agency
Environmental Criteria and
Assessment Office
Research Triangle Park, NC 27711

Dear Dr. Davis:

My comments are specific to the "Exposure Group" and its modeling work group. The "Summary of Exposure Assessment Issues..." by Dr. J. M. Davis received under cover letter dated April 18, 1991 (hereafter referred to as "the summary") is the primary topic for commentary. The summary states on page 4 (line 33 continued to page 5) that the lead ratio model would result in average manganese exposure levels of about 1 ug/m^3 . The correct predicted levels are 0.05 ug/m^3 in cities and, specifically Los Angeles levels of 0.07 ug/m^3 if manganese is used at the maximum requested levels. It is further stated, beginning in line 1, page 5 that "...these results are of a very preliminary nature and are not adequate for use in assessing the health risks associated with MMT use...". I believe the sense of the working group was that: (1) exposure levels were quite low, (2) the three models (SCREAM, lead ratio, SHAPE/BEAM) gave similar predicted levels, and (3) that any/all would be suitable for predicting exposure levels. I believe that John Irwin's comments in his Friday summary made similar points. Any uncertainties discussed by the subgroup were related to microenvironments, the different levels of particulates found by EPA-Ann Arbor compared to Ethyl, and resuspension of particles in indoor environments. These were considered as secondary issues and had no relation to the task of estimating average outside ambient exposures.

I understand that Dr. Davis' comments did not cover the Friday summary session results, and this may be the reason for some of the differences noted.

Sincerely,



Ben F. Fort, Jr., Ph.D.
Senior Mathematics
and Statistical Associate

BFF:cr
cc: Mr. F. W. Brownell
Dr. L. D. Grant
Dr. Judy Graham
Dr. G. L. Ter Haar
056BFF91

ETHYL CORPORATION
Health and Environment Department

Air Conservation

May 13, 1991

Ethyl Tower
451 Florida Street
Baton Rouge, LA 70801

J. Michael Davis, Ph.D.
Health Scientist
Environmental Criteria and Assessment Office (MD-52)
U.S. Environmental Protection Agency
Research Triangle Park, North Carolina 27711

Dear Dr. Davis:

Attached are my comments regarding the Mn/MMT workshop held in Research Triangle Park March 12-15. My comments are directed toward the overall conference and the Neurotoxicology Section that I participated in. One major concern is the very high exposure levels proposed for use in health research by some participants in the neurotoxicology section. Despite being charged with recommending research relevant to lowering the uncertainty of risk assessment associated with the use of MMT in unleaded gasoline and being reminded of this at the Thursday morning plenary session by Dr. Zenick, this was not done. When I tried to point out during the workshop that the research recommendations should be geared toward lowering the risk uncertainties, the Session Chair responded "MMT is not on the table."

In addition, the draft report completely ignores the conclusions of most of the participants on the Friday morning session. It was generally agreed that exposures from MMT use in unleaded gasoline would be quite low. In fact, one EPA staffer stated "...you have infinitesimal increase in background...". The feeling of most participants on Friday was that while it would be good to know more about manganese toxicity, this knowledge would not necessarily be relevant to the MMT issue.

Thank you for the opportunity to comment on the draft report on the meeting. Specific comments follow.

Sincerely,



Gerard D. Pfeifer, Ph.D., CIH
Senior Research Associate

GDP:cr
Attachment

cc: Mr. F. W. Brownell
Dr. L. D. Grant
Dr. Judy Graham
Dr. G. L. Ter Haar
110GDP91

Comments on Draft of "Final Report on Health Research Issues
Associated with the Use of MMT in Gasoline: Workshop Proceedings and
Research Issue Papers"

Page 7, 1st Paragraph

The Decision Tree as presented was taken to be the basis of discussion by the Chair of the Neurotox group. There was no acceptance or rejection allowed. To state "...the majority of the participants agreed in principle..." is certainly overstating the case since we were not allowed to disagree.

Page 8, 1st Full Paragraph

Most members of the CNS work group did not believe that studies on adult and infant primates is a top priority. In fact, the consensus of the group was that a rodent study should be conducted first (see next paragraph). It was suggested that rodent studies should be carried out at 80 mg/m³. This level is at least 800,000 times exposure levels that would result from both MMT-related and background exposure levels if MMT were used in all gasoline.

Page 21, Task B.1

Only one participant was supportive of the use of position emission topography (PET) to diagnose changes in the brain.

Page 23

There appeared to be a lack of awareness by the participants that literature reports exist on both primates and rodents relative to MMT combustion product toxicity. There is a wealth of data already available, but there was no suggestion of a literature review as a starting point. Many of the questions asked have already been answered.

Page 24, Task D

Certainly, inhalation would be the route of exposure that should be used because of the suggestion by some that manganese is somehow more toxic via inhalation than it is by ingestion. There are several reports on exposure of primates to Mn₂O₄ already in the scientific literature. In most, if not all of these, the investigators were unable to generate adverse effects in primates via inhalation of manganese, even at high doses. In those studies reporting adverse effects from manganese, the manganese exposures are virtually always by ingestion or injection, and then effects are only seen with massive doses.

-2-

Pages 50-51

The discussion of testing the developmental neurotox of manganese presupposes a significant increase in exposure of children from MMT use. The exposure work group showed that exposure to children would not significantly increase, either via inhalation or by ingestion of dust/soil. Therefore, these studies have little or no relevance to MMT.

Page 55 - 2nd Paragraph

Dr. Hochberg showed rather convincing evidence that manganism and Parkinsonism are two distinct diseases with separate etiologies. It is true that it has been suggested that they are related, but reference should be made to the more recent research showing that they are different.

Page 58 - Last Paragraph

Exposures of 30 mg/m^3 have no relation to MMT. This is at least 300,000-600,000 times ambient airborne levels ($0.05\text{-}0.010 \text{ ug/m}^3$) projected if MMT is used in all gasoline. This includes background, i. e., non-MMT related manganese. The proposed test levels of 30 mg/m^3 are over a million times the projected increase in manganese levels in ambient air that would result from MMT use. The exposure levels proposed would be likely to overcome the homeostatic processes that normally control manganese levels in the body. Therefore, it would be extremely difficult to extrapolate adverse effects to exposures resulting from MMT use.

Comment on "Summary of Exposure Assessment Issues Discussed at the Manganese/MMT Conference, March 12-15, 1991"

Pages 4-5

Calculations using lead as a surrogate for manganese suggest a maximum, not average, inhalation exposure of 0.1 ug/m^3 , not 1 ug/m^3 . Maximum means cab drivers in Los Angeles would average about 0.1 ug/m^3 . Urban ambient airborne concentration would be about 0.05 ug Mn/m^3 as opposed to present levels of about 0.03 ug Mn/m^3 .

110GDP91

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May 13, 1991

BY TELECOPY

Dr. J. Michael Davis
U.S. EPA Environmental Criteria
and Assessment Office
Research Triangle Park, NC 27711

Dear Dr. Davis:

Although I was not sent a copy of the draft "Final Report on Health Research Issues Associated with the Use of MMT in Gasoline: Workshop Proceedings and Research Issue Papers," as a participant in that workshop (see, e.g., page 29 of the draft report), I am providing comments on that draft.

First, as I am sure by now you are well aware, the draft does not reflect the final plenary session on Friday, March 15. That final session was critical since it provided an opportunity for the health, exposure and environmental work groups to refine their recommendations in light of the findings of the other groups. In particular, as I recall the sense of that session, those present felt that much of the recommended health research would be unnecessary (at least as related to a renewed request from Ethyl Corporation for a fuel waiver for MMT) if, as postulated by the exposure work group, use of MMT would result in only a small incremental increase in ambient manganese levels. Thus, many of the health recommendations were directed to questions about manganese exposures generally (e.g., occupational exposures), not towards the impact of approval of MMT for use in gasoline.

With regard to the impact of MMT approval, the first priority emerging from the plenary session was confirmation that the increase in human exposure to manganese as a result of MMT usage would be very small. Those who had performed analyses using the SCREAM II model and the lead analogy were asked to prepare papers on their work and John Irwin indicated that he wished to compare their findings with predictions from the SHAPE-BEAM model. If the insignificant increases in exposure were confirmed, it was the sense of the group that little if any further health research would be needed to support a conclusion

HUNTON & WILLIAMS

Dr. J. Michael Davis
May 13, 1991
Page 2

that MMT use would cause a significant increase in health risk from manganese.

If a health priority was established, it was for a comparison of the pharmacokinetics of different species of manganese (e.g., MnO₂ versus Mn₃O₄). The reasoning was that if the species were equivalent, one would have additional assurance that the marginal increase in ambient manganese resulting from use of MMT would not pose a significant risk to health.

My other comments concern the reproductive and development specialty section of which I was a member. In general, I believe that the discussions and recommendations of this group (whether or not I agreed with them) are fairly characterized. I would add, however, that while subchronic loading with manganese may answer the question whether or not manganese is a reproductive or developmental toxin, it will not address the question of whether such effects could result from MMT usage unless the levels studied include consideration of the minute increases in inhaled manganese that would follow MMT usage.^{1/}

With regard to the protocol for a study of neonatal oral exposure to manganese, that was indeed the recommendation of the reproductive and developmental effects specialty group. I believe, however, that the plenary session on Friday resolved this issue. There appeared to be general agreement that the incremental impact of MMT (even after it had been used in gasoline for thousands of years) on ingestion of manganese would be so minute that it did not merit further study.^{2/} Therefore, I believe that this recommendation should be omitted.

Finally, it merits noting that the RfC includes a factor of three conservatism to reflect the Agency's concern that the measured exposure levels in the Roels, et al. study (the study on

^{1/} Page 50 of the draft report indicates that some participants felt that developmental neurotoxicological studies were not needed due to a lack of oral or inhaled manganese exposure. To the contrary, the point is that most individuals have a baseline manganese intake that dwarfs the manganese exposure that would result from use of MMT.

^{2/} Given the high concentration of manganese in soil, the increase in the dose of manganese to a child engaging in pica will be essentially undetectable.

HUNTON & WILLIAMS

Dr. J. Michael Davis
May 13, 1991
Page 3

which the RfC is based) may have exceeded past exposures associated with the reported effects. As Attachments 1 & 2 to this letter indicate, both the manager of the plant involved and the senior investigator for the Roels study have recently stated that this concern is unfounded. This suggests that the RfC is high by at least a factor of three. At a minimum, recognition that the measured exposures are representative of past exposures should reduce any uncertainty about the adequacy of the RfC to assure the absence of appreciable risk. This, in turn, should increase confidence that manganese emissions associated with the use of MMT would not pose an adverse health risk.

I hope that these comments are useful to you and I request that, if another draft of the document is circulated to workshop participants, you include me among those receiving that material. If you have any questions concerning the issues that I have discussed, please call me at 202/955-1525.

Very truly yours,

Lucinda Minton Langworthy by KLF
Lucinda Minton Langworthy

UNIVERSITÉ CATHOLIQUE
DE LOUVAIN



FEB 25 REC'D

FACULTÉ DE MÉDECINE
UNITÉ DE TOXICOLOGIE INDUSTRIELLE
ET MÉDECINE DU TRAVAIL
CLOS CHAPELLE-AUX-CHAMPS 30 — Bte 30-34
1200 BRUXELLES
Prof. R. LAUWERYS

Brussels, February 14, 1991

Dr D.R. LYHAM
Director
Air Conservation and Industrial
Hygiene
Ethyl Corporation
451 Florida Street
Baton Rouge
LA 70801
U.S.A.

Dear Dr Lynam,

Regarding the intensity of past exposure to manganese in the manganese oxide and salt producing plant surveyed in 1986, I can state the following. As indicated in our paper, no environmental monitoring data were available to characterize the past pollution of the various workplaces. However, although the plant has expanded since it started production in 1964 and although the number of workplaces has increased, the production processes have remain identical and the workers have always performed the same types of activities. Hence, I am enclined to believe that the exposure of each worker has not drastically changed with time and the airborne concentrations of manganese measured during the survey are likely to be representative of the past environmental pollution. This was also the opinion of the chief foreman.

Do not hesitate to contact me, if you need additional information.

Yours sincerely,

Professor R. LAUWERYS

Attachment 1

FEB 20 REC'D

Tertre, 4 février, 1991

0136

N. REF.:
V. REF.:

FD910112/DH

ETHYL CORPORATION
D. LYNAM, PhD
Director, Air Conservation and
Industrial Hygiene
ETHYL TOWER
451 Florida
BATON ROUGE, LA 70801
U.S.A.

Dear Dr. Lynam.

Re: Toxicological study performed at SEDEMA during 1982-83

Please find hereafter our opinion concerning air concentrations of manganese prior to and at the time of the study.

From 1976 on, SEDEMA had several important increases of capacity in the ore storage, preparation, milling and roasting sections together with facilities producing new salts and oxydes.

Those new processes and equipments were built using best technologies available at that time.

On the other hand, those facilities were added by area extension and this could not lead to raising exposure.

Simultaneously, manpower in the manganese plant went from 111 people in 1976 to the level of 147 people in 1982 and years of exposure have been taken into account in the study.

We consequently consider not correct the assumption meaning that occupational exposures were lower before the study. This opinion is shared today by Prof. Lauwerijs himself.

Hoping the above statement answers your concern regarding Mn air concentrations and exposures at SEDEMA, we remain

Sincerely yours.



F. DELLOYE

Process - Environnement

cc: C. Shaper-Chemetals



M. FAUTSCH

Director
Industrial Development**sedema**

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GENERALE DE BANQUE : 273-0010015-86
R.C. BRUX 62171 - T.V.A. 403.045.985

Attachment 2

ETHYL CORPORATION
Health and Environment Department

Donald R. Lynam, Ph.D.
Director, Air Conservation
and Industrial Hygiene

July 10, 1991

Ethyl Tower
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Baton Rouge, LA 70801
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Cable Address: ETHYLB
TELEX 586-441

J. Michael Davis, Ph.D.
United States Environmental Protection Agency
Environmental Criteria and Assessment Office (MD-52)
Research Triangle Park, NC 27711

Summary of Manganese/MMT Conference

Dear Dr. Davis:

Thank you for the opportunity to review the most recent draft "Summary of Research Issues Discussed at the Manganese/MMT Conference, March 12-15, 1991." On behalf of Ethyl Corporation, I offer the following comments.

This draft appears to be a significant improvement over the previous draft that I reviewed. For example, it emphasizes that the report does not constitute either ORD's or EPA's recommendations for research on MMT or manganese (p. 2). Nevertheless, in light of the stated purpose of the workshop "to define research that will enable a more quantitative health risk assessment of MMT as added to unleaded fuels" (p. 2), and the recognition that exposure information is an important consideration in the preordination of research needs (p. 13), I was surprised that the draft report does not reflect the consensus in the final plenary session that the level of incremental exposure to manganese resulting from the use of HiTEC 3000 will be so low that further health research is unnecessary to reach a conclusion about the acceptability of the Additive. Attempting to prioritize health research needs (p. 13) without acknowledgment of the magnitude of incremental exposure is misleading. As pointed out in my comments of May 13, health research needs must be discussed in conjunction with expected exposure.

In addition to this general concern, Ethyl has two specific concerns with the draft report. First, the draft report indicates that "an average tailpipe-out Mn emission rate of 30% appears to be a reasonable estimate" (p. 5). Testing by both EPA and Ethyl, however, has shown an average emission rate in the 10-15% range. A 30% emission rate therefore is an extremely conservative, upper bound estimate.


Second, the report implies that little is known about the effects of Mn_3O_4 on health. For example, on page 13, it is suggested that "human and/or animal studies might be required . . . to devise a new R_fC based on Mn_3O_4 ." The workshop participants, however, discussed the many studies that have been done on Mn_3O_4 using animals, the experience with use of the Additive in Canada, and the

-2-

trivial addition to total manganese exposure that would result from approval of HiTEC 3000 for use in the United States as reasons why new studies on Mn_3O_4 were not necessary. Moreover, the Roels-Lauwerys study, on which the present R_fC is based, was carried out at the world's largest Mn_3O_4 production facility, and therefore is a reasonable basis for deriving an R_fC applicable to Mn_3O_4 as well as other forms of manganese. The report and/or appendices should include this information.

Finally, I regret the lack of an opportunity to review the appendices, which I understand have been substantially revised. Since much of the substance of the previous draft of this report was contained in those appendices, I am unable to assess whether the final product will accurately summarize the workshop without reviewing the appendices as well as the body of the report.

Sincerely,



Donald R. Lynam, Ph.D., CIH, PE
Director, Air Conservation
and Industrial Hygiene

DRL:cr
cc: Mr. F. W. Brownell
Dr. Judy Graham
Dr. Lester D. Grant
Dr. G. L. Ter Haar
199DRL91

CLEMENT

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Environmental and Health Science

April 29, 1991

Dr. J. Michael Davis
Health Scientist
U.S. EPA
Environmental Criteria and Assessment Office (MD-52)
Research Triangle Park, NC 27711

Dear Dr. Davis:

I am replying to your April 18 letter requesting comments on the first draft Summary Report of the Mn/MMT Workshop. Because I attended the exposure assessment sessions on Wednesday afternoon and Thursday, including meetings of the Field Data Subgroup, my comments apply to the exposure assessment draft.

The report does not address the plenary sessions of the Workshop. These sessions include the Wednesday morning session at which both health and exposure issues were discussed, the Wednesday afternoon plenary session of the exposure group, and the Friday morning wrap-up session. The descriptions of the subgroup reports are accurate as far as I can tell, but without being placed in context by describing the overall discussions and conclusions of the exposure group, the subgroup meeting descriptions do not give an accurate impression of the meeting.

Regarding the Wednesday morning plenary session, I sent a copy of the analysis on which my talk was based to Laura Saeger of ABB. I was recently informed that, because the paper was given in the Workshop rather than in the Symposium, it would not be included in the Symposium proceedings. This being the case, I think that it would be appropriate to have it included in the Workshop proceedings. I hope that you will discuss the coordination of the Symposium proceedings sections with those from the Workshop with those working on the Symposium proceedings, and that these discussions will include the appropriate place in the proceedings for my paper. Please let me know if you would like a copy; ABB has one.

My impression of the Wednesday afternoon exposure group meeting was that the group concluded that the ORD exposure assessment apparently overestimated exposures that would occur with MMT use, based on analyses conducted after the ORD risk assessment was published. New exposure analyses (Gerry Anderson's SCREAM calculations, Ralph Roberson's and Jerry Pfeifer's calculations based on the Aziz data) were consistent in predicting lower

exposures for highly exposed population subgroups. Ambient data from Toronto were also discussed that indicated comparatively low concentrations.

The group consensus was that population and micro-environment exposure data from Toronto should be collected. Also, John Irwin volunteered to run SHAPE/BEAM to predict manganese exposures. The group view was that if the results of SHAPE/BEAM corresponded with the other estimates and measurements, exposure analysis would be in good shape. John Irwin's presentation on Friday morning should be reviewed to give a broader sense of the exposure discussions.

Based on this Wednesday discussion, I do not agree with nor understand the basis for the comment on the pages 4-5, that

"Preliminary results using Pb as a surrogate for Mn suggest that use of MMT in vehicular fuels would result in an average exposure to the urban adult population of about $1 \mu\text{g}/\text{m}^3$. However these results are of a very preliminary nature and are not adequate for use in assessing the health risks associated with MMT use in vehicular fuels."

The $1 \mu\text{g}/\text{m}^3$ exposure estimate should be checked against Jerry Pfeifer's paper; my understanding is that his analysis indicates that urban exposures would be under $0.1 \mu\text{g}/\text{m}^3$.

I also do not understand why these results are characterized as "of a very preliminary nature," nor do I recall the lead analysis being characterized this way at the meeting. Using data on lead exposure is a technically sound way to estimate manganese exposure. Because lead and manganese can be expected to behave similarly in the environment, measurements of lead exposures can be used to estimate exposures that would occur with MMT use, when adjustments are made for the different concentrations of lead and manganese in gasoline and for background exposures. The Aziz data, collected many years ago when all gasoline contained lead, is particularly relevant to the assessment of exposures to highly exposed groups, because these data include measurements of lead exposures by Los Angeles taxi drivers.

An important consensus of the exposure group, not reported in the draft summary, was that if exposures are well below the RfC, as appears to be the case, then many research questions were irrelevant. This observations includes both health issues and additional studies to refine exposure analysis. For this reason, I disagree with the characterization on page 7, bottom, that the Summary describes "the minimum data information and research development projects that must be obtained/executed to quantitatively assess the risk to humans..." and "The focus is on what analyses and data collections are considered absolutely

essential for an adequate risk assessment." This characterization is inaccurate. As noted above, many exposure and health assessment questions are relevant only if significant exposures are likely, which is not the case.

Second, the subgroups were not charged to define "what analyses and data collections are considered absolutely essential for an adequate risk assessment." These discussions focused on analyses that were (1) possible, and (2) desirable to improve our overall understanding of environmental exposures to manganese. An indication of how the subgroups approached their subject can be inferred from the description in Attachment #1, Task #1, (this was the subgroup in which I participated). As you will note, the first recommendation concerns the general analysis of existing databases for a variety of elements (Mn, Fe, Si, Al, Pb) to better understand background exposures. This recommendation to make better use of available data on crustal minerals including manganese was seen as an analysis worth doing, given the availability of data. It was not seen as "absolutely essential for an adequate risk assessment," since it has little to do with a risk assessment of MMT use.

I hope that these comments are helpful to you; please call me or write if I can be of further assistance.

Sincerely,



Chris Whipple, Ph.D.
Vice President

Systems Applications International

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A Division of Clement International Corporation
Environmental and Health Sciences

April 26, 1991

J. Michael Davis, Ph.D.
Environmental Criteria and Assessment Office (MD-52)
U.S. Environmental Protection Agency
Research Triangle Park, North Carolina 27711

Dear Dr. Davis:

I appreciate the opportunity to review and comment on the draft summary report of the Mn/MMT Workshop. My most substantive comment deals with the absence of any writeup that summarizes the Friday morning (March 15th) Plenary Session. During that session we heard a summary of the health effects issues and a recommended research plan. A number of interesting and important research projects were discussed. I came away from these discussions with the understanding that much more can be learned about manganese and its effect on human health.

Following the health effects discussion, John Irwin, EPA/AREAL, summarized the results from the exposure assessment sessions. This discussion appeared to better focus, and perhaps redirect, the health effects issues. That is, while there are important data gaps to be filled with respect to the effect of manganese on human health, this is true regardless of whether MMT is used in unleaded gasoline. In other words, use of MMT in gasoline will not significantly change our environmental exposure (i.e., inhalation or ingestion) to manganese. In sum, if the Mn/MMT Workshop report is to be "accurate", it must include an integration of the health effects and exposure assessment sessions.

Inasmuch as I participated in the exposure assessment sessions, the remainder of my comments will address the Exposure Assessment Summary.

Page 4, Line 15

A sentence should probably be added to acknowledge that current EPA testing results show that manganese emissions, expressed as a percent of input manganese, average about 15 percent.

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Page 5. Line 1

The " $1 \mu\text{g}/\text{m}^3$ " is either a typographical error or a transcription error. My notes indicate that the results, based on using lead as a surrogate for manganese, suggest an average ambient manganese concentration of 0.06 to $0.08 \mu\text{g}/\text{m}^3$ due to the use of MMT in unleaded gasoline. Moreover, because of the lead in gasoline to MMT in gasoline analogy, it is not clear why the summary concludes, "these results . . . and are not adequate for use in assessing the health risks associated with MMT use in vehicular fuels."

Page 7. Lines 30-31

The sentence "[t]he focus is on what analyses and data collections are considered absolutely essential for an adequate risk assessment" (emphasis added) is overstated. For example, some of the analyses suggested in Task 1 (e.g., establish signature pattern of crustal elements - Fe, Si, Al, Mn and Pb in the samples from THEES and PTEAM) cannot be considered absolutely essential in conducting a MMT risk assessment. Other examples can easily be cited. While I do not take issue with the tasks and their descriptions, I do believe that the above-cited sentence needs to be softened in order to be correct.

If you have any questions concerning my review comments, please do not hesitate to call.

Respectfully submitted,



Ralph L. Roberson, P.E.
Vice-President

RLR/chw

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To: J. Michael Davis, Ph.D.

From: H. Daniel Roth

Subject: Comments on the Latest Draft of the EPA Mn Research Proposal

Date: May 13, 1991

In general, I felt that the latest draft of the epidemiology research proposal circulated by EPA captured the topic matters that were discussed at the epidemiology workshop, but it failed to reflect the groups assessments of the chances of success of different projects. For example, while, as the proposal indicates, there was lots of discussion about conducting an epidemiology study in Montreal, few members of the group felt that such a study would have any chance of achieving its goals. Ambient levels of Mn even in the most polluted areas of the city are far too low to be associated with any detectable health trends.

In summary, the following tasks were discussed at the workshop: (1) conducting a new occupational study under idealized conditions; (2) conducting a community epidemiology study in Montreal; (3) carrying out an occupational study among highly exposed individuals in Montreal such as parking lot attendants; (4) conducting an epidemiology study in third world polluted countries; (5) reanalyzing the Australian deGroote Island data; (6) reanalyzing the data in the Roels, Ingren, Saric, and other historical studies.

It would be nice to carry out the idealized occupational study (item 1), but it is doubtful whether the design setting described in the proposal exists anywhere in the world. In other words, this part of our recommendation was wishful thinking. Also, most of the committee members felt, as I did, that there was little chance that a study in Montreal would be worthwhile conducting (items 2 and 3) because, as stated above, ambient levels are too low to cause Mn-related diseases.

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Furthermore, because it might be impossible to separate out Mn effects from the effects of other pollutants present in the ambient atmosphere, it is questionable whether it would be advisable to conduct any studies in third world countries (item 4).

On the other hand, the committee and I felt that there might be much payoff in reanalyzing the Australian data (item 5) and some of the occupational data reported in the literature (item 6). Because of the high levels of Mn in the area, the Australian data is probably the best community information that one can hope to get. As the members of the CNS Specialty Section, we in the Epidemiology Section felt that some of the old occupational data were not completely analyzed or were not analyzed correctly. A reanalysis of the occupational data would not only provide new information on LOAELS and NOAELS but might also yield valuable information in helping design a new occupational study if this were deemed necessary.

Also, it would be valuable to carry out the research proposal advanced at the plenary session to re-examine the individuals in Taiwan and Chile who contracted manganism as a result of massive doses of Mn exposure (i.e. over 10 mg/m³) many years ago. If the symptoms of the disease among these individuals are not as pronounced as they were years ago, then it will be known that the effects of manganism are reversible. This would be an important finding as a result of a relatively minor effort.

Taking into account the above observations, we can now address the question advanced to the epidemiology group: Is an epidemiology study of oxides of manganese feasible? The answer is that much can be gained by reanalyzing existing epidemiological and occupational data, which strongly suggests that there are no effects at levels of Mn below 500 µg/m³. On the other hand, it is not worthwhile to launch a new epidemiological or occupational study. The results from such a study probably will not have much chance of yielding information that cannot be gleaned from already existing studies. All of my comments are for oxides of manganese in general. To find data on MnO₂ specifically would be even more difficult.

The relationship of the recommended research to the question of MMT use is a separate question that was not addressed by the

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Epidemiology Section. It is my impression that the conclusion of the final combined workshop session was that this research was not necessary prior to a decision on MMT use but that it would provide useful information on the consequences of exposure to high levels of manganese. Since the existing data suggest no effects from manganese exposures below $500 \mu\text{g}/\text{m}^3$, and since the information presented at the Workshop by the Exposure Group strongly suggests that exposures would be about four orders of magnitude below that level following MMT use, I concur with that conclusion.

Below are more in-depth comments.

1. It would be nice to carry out the study outlined in the proposal, but there is little possibility that this study would show anything. Earlier studies (e.g. Saric) showed that there is little reason to believe that Oxides of Mn are associated with Central Nervous System (CNS) effects at levels below $300 \mu\text{g}/\text{m}^3$. (Saric considered three exposure groups -- high, low, and medium Mn exposures -- and found a greater incidence of effects among the low exposure group than among the medium exposure group. This result is counterintuitive if the effects observed in Saric are due to Mn exposures).
2. Even more important, it is highly unlikely that data could be found that comes close to resembling the ideal study outlined in the mock study design. Exposure conditions in occupational settings rarely are as neatly delineated as in the mock study design. In addition, the historical data on exposures that will be needed almost never exist or are of such poor quality that they are useless for epidemiological study.
3. For the above reasons, only a low priority should be placed on conducting the idealized study described in the proposal.
4. Because of the small number of women working in industrial environments, it would be even more difficult to conduct occupational studies on women.
5. Like the majority of the epidemiology committee, I also feel that it would be a waste of resources to conduct a community epidemiology study in a location like Montreal where MMT has been in use as a fuel additive for several years.

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6. Based on the occupational data, CNS effects first begin to occur at Mn levels of 1 mg/m^3 which is a thousand times greater than the average ambient levels in Montreal. At such low ambient levels, the incidence of CNS and/or respiratory effects will be so extremely low (if present at all) that it is highly doubtful that any reasonable epidemiology study will be able to identify them.
7. In addition, with Mn exposures being highly variable over the city, it will be extremely difficult and costly to characterize individual exposure conditions over the course of a day. Coupled with the problems of characterizing exposures, any epidemiology study will have serious confounding problems.
8. For several reasons, even a study of selected highly exposed groups in Montreal, such as parking garage attendants, has a low chance of identifying reasonable LOAELS or NOAELS levels. First, such individuals do not work long enough under high exposure conditions to suffer from Mn effects. Second, they are the healthiest segment of the population and the least likely to show effects.
9. Third, even parking lot attendants are exposed to relatively low levels of Mn. Thus the incidence of Mn-related diseases is bound to be extremely low and an enormous population will have to be studied to detect any trends of disease. In all likelihood, there is not a population large enough in Montreal for such an undertaking.
10. Some of the committee members felt, as I did, that there would be little promise in conducting an epidemiology study in third world polluted cities such as Mexico City or mining towns in Yugoslavia.
11. Even in these highly polluted areas, it is doubtful that Mn levels are elevated enough to be associated with adverse health effects. Also, in third world polluted locations, it would be difficult to isolate the effects of Mn exposures from the effects of a host of other pollutants that usually covary with Mn.

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12. Unlike the above proposals, which had little chance of success, the committee and I felt that it would be highly beneficial to reanalyze the Australian data if they could be made available. In this study, the Mn levels were sufficiently high to determine once and for all if there are adverse health consequences associated with Mn exposures anywhere approaching ambient levels.
13. The monitoring data and the health data in the Australian study appeared to be of high quality. In addition, the study cohort included women, a segment of the population excluded from all earlier epidemiology studies, as well as sensitive populations such as children and the elderly.
14. Finally, because the data are already collected and computerized, it would be relatively inexpensive to analyze them over a short period of time. All the other tasks discussed above entail data collection activities that might take years to complete.
15. Another task that should be given high priority is reanalyzing the data in some of the old occupational studies such as Saric, Roels, Chandra, and Ingren. For the most part, the data in these studies were not completely analyzed or were manipulated using poor quality statistical methods. A reanalysis of these data might yield much new information on NOAELS as well as how to conduct new occupational studies. Also, the results from such a reanalysis can be completed in a relatively short period of time.
16. Finally, a relatively minor effort that might have important consequences is a follow up examination of the individuals in Taiwan and Chile who contracted manganism as a result of massive exposures to Mn (i.e. 10 mg/m³ or higher) over ten years ago. If the symptoms of manganism have abated in these individuals, it will be known that, unlike the lead model, the effects of manganism are reversible even under extreme conditions of exposure.



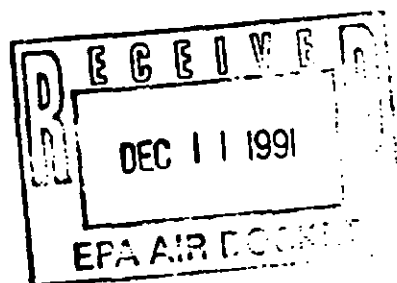
UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

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OFFICE OF
AIR AND RADIATION

Honorable Henry A. Waxman
Chairman, Subcommittee on Health
and the Environment
Committee on Energy and Commerce
House of Representatives
Washington, D.C. 20515



Dear Mr. Chairman:

Please find enclosed our responses to questions from your July 22 hearing regarding WEPCO. Responses to questions in your August 12 letter will be answered shortly. If I can be of further assistance, please let me know.

Sincerely,

A handwritten signature in cursive script, appearing to read "William G. Rosenberg".

William G. Rosenberg
Assistant Administrator
for Air and Radiation

Enclosure